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U. S. ARMORED CRUISER *MONTANA*.

DESCRIPTION OF MACHINERY—OFFICIAL TRIAL.

BY WILLIAM RUSSELL WHITE, LIEUTENANT, U. S. NAVY, MEMBER.

The armored cruiser *Montana* is one of two sister ships (the other being the *North Carolina*) built by the Newport News Shipbuilding and Dry Dock Company of Newport News, Va. The contract for this vessel was signed June 3, 1905, the price being $3,575.000.00, which does not include the armor and armor bolts (exclusive of protective deck), ordnance and ordnance outfit and certain articles supplied by the Government. The contract time for completion was thirty-six months. Owing to various delays, for which the contractors were not responsible, this time was extended, and the ship was delivered July 10, 1908.

The main engines were required to develop twenty-three thousand indicated horsepower when working one hundred and twenty revolutions per minute with a steam pressure of two hundred and fifty pounds at the high-pressure cylinder.

The guaranteed speed of the ship was twenty-two knots per hour for four hours.

PRINCIPAL DIMENSIONS OF HULL.

Length on load-water line, feet	508
between perpendiculars, feet	502
over all, feet and inches	504-06
Breadth, molded, feet and inches	72-06
extreme to outside of plating, feet and inches	72-10½
Trial displacement, tons, about	14,500
draught to bottom of keel, feet	25
Tons displacement per inch immersion at normal draught	59.70
Capacity of engine-room feed tanks, tons	51
reserve feed-water compartments, tons	192

MAIN ENGINES.

There are two propelling engines, right and left, outboard turning when going ahead, and placed abreast in watertight compartments, separated by a middle-line bulkhead.

The engines are of the vertical, inverted-cylinder, direct-acting, four-cylinder, triple-expansion type. The order of the cylinders, beginning forward, is forward low pressure, high pressure, intermediate pressure and after low pressure. The cranks of the two forward engines are opposite, as are the cranks of the two after engines, the first pair being set at right angles with the second. The sequence of the cranks, therefore, is high pressure, intermediate pressure, forward low pressure and after low pressure.

The framing of the engines consists of forged columns trussed by forged-steel stays.

The engine bedplates are of cast steel, in three sections, supported on the keelson plates, and have seatings for the main bearings, columns and the turning engines.

The cylinders and valve chests are of the best quality of cast iron, fitted with working liners of close-grained cast iron as hard as can be properly worked. The space between the cylinder casings and liners and the space between the double walls of both heads are utilized for steam jackets, the steam being supplied at boiler pressure to the high-pressure cylinder

jackets and through reducing valves for the intermediate and the low-pressure jackets, successively, each having its respective drain through a trap to the feed tank.

The high-pressure and the intermediate-pressure cylinders touch at finished surfaces so disposed as to offer constraint against athwartship motion only.

On the casings flanges are cast for securing lagging. There are facings for the crosshead guides and other fittings; and there are brackets for the supporting columns and the tie rods.

The high-pressure piston is made of cast iron, the intermediate and the low-pressure pistons of cast steel, and all followers are of class "A" cast steel.

The high-pressure piston ring is solid, the other main piston rings are cut obliquely and fitted with a brass tongue piece and lug over which is fitted a limiting piece. All these rings are set out with "C" springs, each having equal tension.

Each piston rod is tapered to fit the piston and is secured by a nut having a locking plate. The lower end is fitted to a forged-steel crosshead to which is bolted a cast-steel slipper. This slipper is lined with white metal and works in a single bushing bolted to the cylinder facings at the upper end and to a cast-steel guide of "I" section at the lower end: this girder is supported by the inboard engine column.

The go-ahead guides are iron castings and are made hollow to contain a water jacket; the backing guides are of cast steel and bolted to the flanges on the go-ahead guides.

The connecting rods are high-grade steel forgings, forked at the top to span the crosshead and are "T"-headed at the bottom.

The crank shafts are in two sections, each carrying two cranks, coupling disk and raised seatings for the eccentrics. The latter are made in two parts, bolted firmly in place and secured by a key with adjusting pieces on either side.

The forward section of the crank shaft operates a shaft bilge pump.

The main valves are of the piston type, one for the high-

pressure and two each for the intermediate and low-pressure cylinders. The heads are of cast steel with lap-welded steel-pipe distance pieces riveted on; the packing rings are of cast iron turned larger than the bore of the valve chest, cut obliquely and bolted together to allow contraction but not expansion.

The valve stems carry balance pistons working in cylinders on the upper valve-chest covers; the tops of the high and of intermediate-pressure balance pistons are connected to the low-pressure receiver, and the tops of the low-pressure balance pistons are connected to the main exhaust pipe.

The bottom of the high-pressure valve stem carries composition gibs working in brackets secured to the lower valve-chest covers. The intermediate and the low-pressure valve stems are worked by a crosshead similarly guided.

The valve gear is of the Stephenson type, with double-box links and an independent linking arrangement on the reversing shaft.

REVERSING GEAR.

The reversing gear for each engine consists of a steam cylinder and an oil-controlling cylinder bolted to the high-pressure cylinder. The piston rod of the reversing gear, which is common to both cylinders, acts directly on the arm, keyed to the reversing shaft. The piston rod passes through the controlling cylinder with a uniform diameter.

The valve of the steam cylinder is of the piston pattern, of composition, working in composition-lined valve chest.

There is a by-pass valve on the oil cylinder, worked by a continuation of the stem of the steam-piston valve. These valves are worked by a floating lever, the primary motion being derived from the hand lever on the working platform and the second motion from the reversing shaft, all parts being so adjusted that the reversing shaft follows the motion of the hand lever and is firmly held when stopped. There is a stopcock in the by-pass pipe of the oil cylinder, and a pump for reversing by hand is connected to the oil cylinder with its lever convenient to the working platform. The by-pass pipes

are connected to the valve box of the hand pump in such a way as to leave the hand arrangements always in gear. The piston of the oil cylinder is packed by two cup leathers.

REVERSING SHAFT.

There is one reversing shaft for each engine, with an axial hole through it. It has arms for the reversing engine and for each link. Each reversing arm for the links is made with a slot fitted with a block, to which the extension links are attached. Each block is adjustable in the slot of its arm by a screw and hand wheel of an approved hand-locking device and is fitted with a suitable index. The slots in these arms are so arranged that the links may be thrown into full backward gear irrespective of the position of the block in the slot; and the length of the slots is such that cutoff may be varied from about 0.5 to 0.75 of the stroke.

TURNING ENGINES AND GEAR.

There is installed in each engine room a double engine for turning the main engine with steam of one hundred pounds pressure. This engine drives, by worm gearing, a second worm, which may be made, at will, to mesh with a worm wheel fitted on the crank shaft.

The turning engines have piston valves, and are made reversible by means of Stevenson links, reversed by hand levers.

Each turning-engine shaft is fitted for turning by hand.

The oil service is supplied with oil from a gravity tank fed by a small steam pump with overflow pipe to the pump suction. The piping arrangement is such that oil is distributed to all the oil boxes, which have adjusting valves and wick-feed to pipes leading to all bearings.

Water service is provided for each engine by a four-inch pipe from the discharge side of the main circulating pump. This pipe has suitable branches to the various parts of the engine; the discharge is returned to the suction side of the same pump by suitable pipe connections.

DATA OF MAIN ENGINES.

	H.P.	I.P.	L.P.
Diameter of cylinders, each, inches	38½	63½	74
Stroke, each, inches	48	48	48
Diameter of piston rods, each, inches	8½	8½	8½
Balance pistons, each, inches	7	7	9

VALVES AND VALVE SETTINGS.

	H.P.		I.P.		L.P.	
Number of piston valves, each	1		2		2	
Diameter of valves, each, inches	23		25½		28½	
Travel of valve, each, inches	10½		10½		10½	
Side of valve on which steam taken	inside		outside		outside	
	Top.	*Bottom.*	*Top.*	*Bottom.*	*Top.*	*Bottom.*
Width of port, inches	4.0	4.0	4.0	4.0	4.0	4.0
Steam opening, linear, inches	3 1/16	3 7/16	2 13/16	3½	3 1/16	3½
area, square inches	175.7	189.5	359.8	382.8	422.6	431.2
Exhaust opening, linear, inches	4.0	4.0	4.0	4.0	4.0	4.0
area, square in.	220.5	220.5	490.0	490.0	552.0	552.0
Steam lap, inches	2 1/16	1 13/16	2 5/16	2½	2 5/16	2½
Exhaust lap, inches	—¼	+7/16	—5/16	+9/16	+1/16	+7/16
Steam lead, linear, inches	1/8	7/8	1/4	1½	1/2	1 1/2
Cut off, decimal of stroke, maximum	.835	.776	.777	.695	.788	.695
minimum	.596	.508	.536	.438	.555	.437
Diameter of crosshead bearings, in.	10¾		10¾		10¾	
Length of crosshead bearings, in.	11		11		11	
Diameter of crank-pin bearings, in.	20		20		20	
Length of crank-pin bearings, in.	23		23		23	
Diameter of crank-shaft bearing, in.	18½		18½		18½	
Length of crank shaft bearing, Nos. 1, 2, 3, 4, 5, 6, inches	22½	22½	22½	22½	35	29
Axial hole crank shaft, inches	10		10		10	
Length of connecting rod between centers, inches	96		96		96	
Ratio to crank	1 : 4		1 : 4		1 : 4	

SHAFTING AND THRUST BEARING.

The thrust shaft is complete to the after section of the crank shaft and has twelve collars, between which are fitted cast-steel horseshoes lined with white metal, which are hollowed for circulating water. The horseshoes may be adjusted by nuts on the side rods, which are secured to cast-iron pedestals at each end. These pedestals are bolted to the sole plate, and are capable of being moved in a fore-and-aft direction by adjusting wedges. The pedestals with their ends and side walls form a trough for an oil bath which has in it a cooling coil.

The line shaft is forged on the thrust shaft and continues to the stern tube, where it couples to the stern-tube shafting. The latter is supported by two stern-tube bearings, which are of brass and fitted with lignum vitae.

The inboard coupling of this shaft is made so as to permit the shaft to be drawn outboard.

The outboard body of the propeller shaft is covered with a watertight composition sleeve shrunk on and then pinned.

Each propeller shaft is supported by strut and stern-bracket bearings fitted with lignum vitae bearing surfaces similar to those in the stern tube.

DATA FOR SHAFTING.

Diameter of thrust shaft, inches	17¾
Number of collars	12
Diameter of collars, inches	27
Width of collars, inches	2
Space between collars, inches	4
Length of thrust shaft, feet and inches	25–11½
Diameter of shaft beyond thrust, inches	17½
Length of stem-tube shaft, feet and inches	...
Diameter of stem-tube shaft, inches	18½
Length of propeller shaft, feet and inches	48–5½
Diameter of propeller shaft, inches	18½
Axial hole, inches	10½
Thrust shoes, effective surface, square inches	2,618.52
Length of thrust-shaft bearings, (two) inches	18
line-shaft bearing, (one) inches	26
stem-tube bearings, forward, inches	60½
after, inches	61½
propeller-shaft bearings, forward, inches	35¾
aft, inches	60½

PROPELLERS.

There are two three-bladed propellers, both outboard turning for ahead motion; the blades and hub are of manganese-bronze. The blades are a true screw at 22 feet 6 inches pitch, and the pitch is adjustable by having oval bolt holes in the flange of the blades. The hub is tapered to fit the shaft and keyed, the nut being securely locked. All under-water fittings are covered by casings and fair-water sleeves filled with resin and pitch to make them waterproof.

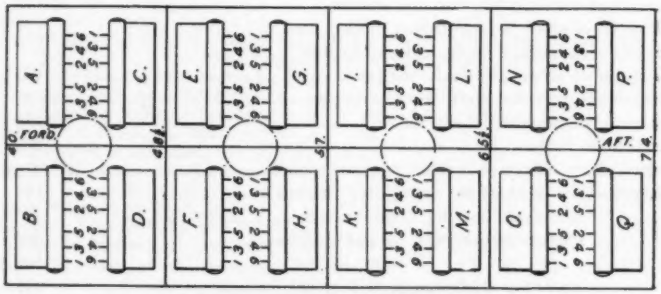
PROPELLER DATA.

Number of propellers	2
blades, each	3
Diameter, feet	18
Pitch as set, feet and inches	21–09

Pitch adjustable from, feet and inches	21–06 to 23–06
Ratio of diameter to pitch	.8
Area, projected, square feet	78
helicoidal, square feet	100
disk, square feet	254.47
Height of lower tip of blade above keel, inches	16.7
Immersion of upper tip of blade at load draught, inches	67.3

BOILERS.

The boilers are of the Babcock & Wilcox type, built and installed by that firm. The battery consists of sixteen boilers in eight watertight compartments, two in each, as shown:



Arrangement of Boilers.

The capacity of the boilers is such that all steam machinery can be run at full power with an average air pressure in the ash pit of not more than two inches of water. All pressure parts are made of open-hearth steel plate and seamless steel tubes with no screw joints exposed to the fire. The general design of the boilers is the usual type built by this well-known firm.

Each boiler has the following fittings:

One main steam stop valve closing toward the boiler and one dry pipe in the steam drum.

One main feed stop valve and check valve, with internal pipe.

One auxiliary-feed stop valve and check valve, with internal pipe.

One surface-blow valve with internal pipe and scum pan and two bottom-blow valves with internal pipes.

One main safety valve and one steam gauge.

Three gauge cocks arranged to operate from the fireroom floor.

Two glass water gauges, one of them being of the Klinger type, both being fitted with quick-closing devices.

One salinomiter pot, one drain cock and one air cock.

One stop valve, three-quarters of an inch in diameter, for cleaning pipe connections.

Two cleaning hose and lances.

One connection for testing water.

Necessary pipes and fittings for attaching all the above to boilers.

Zinc protectors with baskets for catching pieces of disintegrated zincs.

There are air connections for blowing soot off the tubes.

The uptakes have a clear area at all points of one-seventh of the grate, and are provided with dampers and doors for examination of their interior. The space between the inside and middle sheets is open to the air space of the smoke pipe at the top, and is provided with dampers at the bottom for the free circulation of air when forced draft is not used. These two sheets are free one from the other to allow for expansion. The space between the middle and outer sheets is filled with magnesia to prevent conduction of heat, and this lagging extends to the protective deck.

There are four smoke pipes, each about ninety-three feet in height above the grates. The inner casing extends to the top, and the outer casing extends to within eighteen feet of the top, between these two casings is the usual air space. The weight of the smoke pipe is taken by the protective deck. Each pipe divides into four rectangular sections, one for each of the boilers, as shown in the sketch.

DATA FOR BOILERS.

Number and type	16 B. & W.
Height, external, feet and inches	12-01½
Length, external, feet and inches	9-01½
Width, external, feet and inches	16-01½
Number of furnaces, each boiler	2
furnace doors, each boiler	6
headers, each boiler	27
Grate surface, square feet	99.375
Heating surface, square feet	4,250.
Ratio of G. S. to H. S., square feet	42.76
Grates, length, feet	7
width, feet	6.83
Per cent. of air space in grates, inches	35
Test pressure, pounds	400
Working pressure, designed, pounds	265
Number of tubes, 2-inch (No. 8 B. W. G. thickness)	901
4-inch (No. 6 B. W. G. thickness)	57
Smoke pipes, height above grate, feet	92.25
Area of smoke pipe, each, square feet	59.56
Number of smoke pipes	4
Grate area, each group, square feet	397.4
Kind of forced draft	closed fireroom.

ELECTRICAL FIRING DEVICE.

There is an electrical time-firing device in the starboard engine room, which is suitably connected to a gong on the light dials suitably located in each fireroom. The interval of firing the furnaces is controlled from the engine room, and this device is adjustable by seconds up to ten-minute intervals.

MAIN STEAM LINE.

The main steam pipes are arranged symmetrically in two systems, one on each side of the ship, and have an eight-inch branch from the auxiliary steam line in each compartment and so indirectly from each pair of boilers. The sizes of these pipes increase from forward aft, from eight to thirteen inches, the latter diameter continuing to the engines. Slip joints, bleeder pipes and separators are provided, as well as stop valves, which are suitably located in the lines of piping. There is provision for supplying live steam to the intermediate and the low-pressure receivers.

AUXILIARY STEAM LINE.

The auxiliary steam lines are eight inches in diameter and extend fore and aft through the boiler compartments, one on each side of the ship. They are connected with the main stop valves of all boilers on their own sides of the ship, and a cross connection is provided in the forward boiler compartments. Here the auxiliary steam line connects with the manifold which supplies steam to the machinery in the forward part of the vessel. A similar connection aft supplies steam to the machinery in the after part of the ship.

In connection with the auxiliary steam line there are the following systems:

Dynamo steam and exhaust piping.
Evaporator steam and exhaust piping.
Steam heating and pantry systems.
Ice machine steam and exhaust piping.
Anchor engine steam and exhaust piping.
Steering engine.
Galley steam.
Laundry steam.

OTHER SYSTEMS OF PIPING.

Other systems of piping are:
Main feed suction and discharge.
Auxiliary feed suction and discharge.
Bilge suction and discharge.
Reserve feed tank connection.
Distiller and evaporator piping.
Fresh-water piping.
Discharges from pump to fire mains.
Sanitary system.
Water service to main engines.
Drains.
Steam piping to sea valves.
Refrigerator piping.
Ice-machine water piping.

Vapor piping.
Safety-valve escape pipes.
Indicator piping.

TELEGRAPHS AND GONGS.

The engine-room telegraphs and the gongs are of the usual type and are operated from the conning tower, the bridges and the central station.

TELEPHONES AND SPEAKING TUBES.

Telephones of the loud-speaking type are installed so that communication is obtained where needed. Speaking tubes communicate from the central station, from the bridge and from engine room to various other stations.

ASH HOISTS.

The ash-hoist engines were designed and built by the Hyde Windlass Company, and are located in the upper hatches. The ventilators contain the bucket guides, ropes, sheaves, etc. The hoists may be operated either from the main or the upper deck, and are designed to hoist either to the main deck or to the upper deck, the bucket-guide rails extending from the bottom of the ventilator trunk to a point well above the upper deck. There are trolleys at this deck, as well as on the main deck, for delivering ash buckets to the chutes at the ship's side. On a test, three hundred pounds were hoisted from the fireroom floor plates to the upper deck in seven seconds, including starting and stopping, with 150 pounds of steam pressure.

The hoisting engines are of the reciprocating type, with a rope drum, fitted with a follow-up and reversing gear and an adjustable safety gear to prevent overwinding and to stop the engine when the bucket reaches the fireroom floor plate.

DATA FOR ONE ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	4½
Stroke, inches	5
Diameter of drum, inches	5
Number of ash-hoist engines in the ship	4

FORCED-DRAFT BLOWERS.

One forced-draft blower is located in each fireroom, being suspended from the protective deck over the center of the fireroom in its own airtight compartment. The engines and fans were designed and built by the B. F. Sturtevant Company.

Each engine drives two fans, located athwartships, thus delivering the air directly to the fireroom floor plates, about two feet in from the ash pan. The air is supplied from the fireroom ventilators, which are closed at the bottom when under forced draft.

DATA FOR ONE BLOWER ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	6
Stroke, inches	6
Diameter of valve, inches	3½
Valve travel, inches	2
Diameter of piston rod, inches	1⅝
crank shaft, inches	3⅜
pins, inches	3⅜
fan shaft, inches	3⅜
Length of connecting rod between centers, inches	15¾
Number of bearings	3
Total length of bearings, center, inches	3½
end, inches	10½
Crank angle, degrees	180

DATA FOR ONE BLOWER FAN.

Diameter of fan, inches	66
Number of blades	8
Width of tip of blades, inches	16
Area of induction nozzle, square inches	1,383
eduction nozzle, square inches	2,765

FEED AND FILTER TANK.

A feed and filter tank of 6,040 gallons capacity is located on the outboard side of the after end of each engine room. It is rectangular in shape and the top is arranged as a filter, with a capacity of 1,000 gallons; the filtering material is "Loofa," which is placed between the perforated plates. This filtering chamber is divided by vertical division plates so arranged

that the water flows under and over in succession. All the material is of steel which has been galvanized before assembling.

TANKS.

There are oil tanks of 3,000 gallons capacity. There are tallow tanks of 150 pounds capacity. There are two waste tanks of 500 pounds capacity each.

MACHINE SHOP.

The machine shop is located amidships, on a level with the battle gratings and in a compartment of its own between the engine-room hatches. Each machine is directly driven by its own motor. The following machines are installed:

One 28-inch extension gap lathe (11 feet).
One 14-inch engine lathe (4 feet).
Two 12-inch engine lathes (5 feet).
One 16-inch shaper.
One 28-inch vertical drill press.
One 12-inch vertical drill press.
One Universal milling machine.
One 30-inch grindstone.
One 12-inch emery grinder.
One combined hand punch and shears ($5\frac{1}{2}$ inches).
Six bench vises.

All tools are complete and provided with the most modern attachments, including scroll and drill chucks, index heads automatic crossfeed, swivel tables, pipe vises, etc., and all necessary tools, drills and cutters.

HEATING SYSTEMS.

The heating system is divided into five sections, three forward and two aft, each supplied by the auxiliary steam line through stop and reducing valves set at forty pounds per square inch. Three of these sections constitute distinctly separate circuits. One circuit supplies the galley, general mess pantry, bakery and forward laundry; the other, all for-

ward baths, showers, heaters and after laundry; the third, all after bath showers, heaters and pantries. Two sections constitute two distinctly separate radiator systems, which derive their supply from distributing manifolds, one forward and one aft, fitted with independent stop valves; six forward radiator circuits branch off from these manifolds. Whenever the galley and heater circuits change direction to supply remote heaters, suitable cut-off valves are provided. The drains from the forward and the after radiators are divided into three respective circuits and enter separate receiving manifolds forward and aft respectively; the forward and the after galley, pantries and bath circuits lead into separate forward and after traps respectively. The radiator manifolds are each drained by an independent trap.

All traps discharge through main steam drain line into the feed tank and are fitted with suitable by-pass and stop valves to discharge into the starboard auxiliary condenser. The heater-circuit steam and drain pipes are of seamless-drawn brass (iron-pipe size) suitably connected by composition fittings, made tight where passing through bulkheads by stuffing boxes and located as near to the door as possible when passing through store rooms.

Provisions for ample expansion have been made by fitting horizontal copper U bends having the same internal diameter as the connecting pipes. The radiators consist of brass pipes connected by return bends with reduced ends. They are fitted generally with drain, supply stop valves, triangular stems for socket keys, protected by stem guards, but have hand wheels in officers' quarters.

Whenever areas over ten square feet are called for the radiator coils are divided into two parts, unions being fitted on outlet ends of valve to permit of unrestricted removal of coils. In order to expedite service and repairs, all heaters and radiators are tagged by suitable brass tags bearing numbers, odd and even, from forward to aft, on each deck, according to location on starboard and port side, respectively.

REFRIGERATING PLANT.

There are two Allen dense-air ice machines, each capable of producing the cooling effect of two tons of ice per day. The cooling pipes from the machines are led into the ice tank, the scuttlebutts and the cold-storage room.

Valves are provided in accordance with the Bureau of Steam Engineering standard arrangement of valves, in the cold-air pipes of refrigerating plant, so that the air may go to the cold-storage room direct, or through the ice-making tank, and thence to the cold-storage room and scuttlebutts, and also from the ice-making tank direct to the scuttlebutts.

AIR COMPRESSORS.

There are three Westinghouse air compressors in the after part of the port engine room for use in running pneumatic tools in the Steam Engineering department, for blowing soot off the boiler tubes, and for the gas-ejecting system for the guns.

Each compressor has a capacity of about fifty cubic feet of free air per minute, at one hundred pounds pressure. The compressor is driven by steam.

CONDENSERS.

Main Condenser.—There is one main condenser in each engine room, oval in form, the inside dimensions being 9 feet 4 inches high, 5 feet 8 inches wide, the top and bottom being struck with a radius of 2 feet 10 inches. The shell is $\frac{5}{16}$-inch thick, with two double butt joints, and with circumferential and longitudinal angle and T-bar stiffeners.

The water chests are cast $\frac{5}{8}$-inch thick. The forward chest, being the one for the entrance and exit of circulating water, has a horizontal division plate in the middle fitted with valves which, when open, allow the circulating water to pass overboard direct, the valves being worked by a lever on the outside of the condenser, and it has nozzles for inlet and outlet of circulating water 21 inches in diameter.

The condenser-tube sheets are rolled, each in one piece. They are 1 inch thick, with smoothly finished holes for the tubes, tapped and fitted with screw glands for packing the tubes.

There are 6,292 seamless-drawn tubes in each condenser, $\frac{5}{8}$-inch outside diameter, No. 16 B. W. G. in thickness. The tubes are 14 feet and $\frac{1}{2}$ inch long between tube sheets and are spaced $1\frac{5}{16}$-inch between centers. They are supported at two intermediate points by ferrules, $\frac{3}{4}$-inch long, inserted in supporting plates. Baffle plates are fitted to direct the steam over all the tubes.

The cooling surface for each condenser is 14,411 square feet, measured on the outside of the tubes.

The condensers are supported by angle plates riveted between circumferential angle-bar stiffeners.

There is riveted to the shell of each condenser a casting with two composition nozzles with faced flanges 27 inches diameter of opening, for attachment of the main exhaust pipes, and a faced flange, 9 inches in diameter of opening, for the auxiliary exhaust pipe.

Cast-steel flanges are riveted to the shell of each condenser and properly faced for an air-pump suction pipe 13 inches in diameter and for two manholes at the bottom 12 inches in diameter. There is a 1-inch connection in the bottom manhole for cleaning the tubes by boiling.

Drain cocks are provided with pipes leading to the bilge.

A copper tank is provided for admitting an alkaline solution into each condenser, the tank having a capacity of five gallons. Zinc protectors and safety valves are fitted.

The material of the condenser is as follows: Shells, steel, class B boiler plate. Baffle plates, steel, class C boiler plates. Tubes, composition: copper 70, tin 1, zinc 29 per cent. Tube sheets and supporting plates are as near as possible the same material as the tubes. Glands are of tubing, and of the same composition as the tubes. Water chests are of composition. All bolts are of bronze.

MAIN AIR PUMPS.

There is one independent air pump for each main engine, which is capable of maintaining a vacuum of twenty-five inches at full power. Each is double, vertical and single acting, with two inverted steam cylinders. The suction opening is thirteen inches and discharge is eleven inches in diameter.

The casings are of composition, the steam cylinders are cast iron and air-pump brackets are of composition.

MAIN CIRCULATING PUMPS.

The circulating water for auxiliary condenser is supplied by a centrifugal pump having double inlet valves, and it is driven by an independent compound engine of sufficient power to discharge 15,000 gallons of water per minute when making two hundred and sixty-five revolutions per minute.

AUXILIARY AND DYNAMO CONDENSERS.

The material of these condensers is as follows: Shells, steel, class B, boiler plate; tubes, composition, copper 70, tin 1, zinc 29 per cent.; tube sheets, as near as possible of the same material as the tubes; heads, composition.

The cooling surface of the auxiliary condensers is 600 square feet, and of the dynamo condensers 700 square feet, measured on the outside of the tubes.

In each engine room there is an auxiliary condenser connected from the auxiliary exhaust pipe to all the auxiliary machinery. Each condenser has a combined air and a circulating pump.

For each dynamo room there is an auxiliary condenser for the exclusive use of the dynamo engines. Each has a combined air and circulating pump. The tube sheets are one inch thick. The diameter and spacing of the tubes and the packing are the same as in the main condensers.

The tubes of the auxiliary and dynamo condensers are of the same length.

EVAPORATOR AND DISTILLING PLANT.

The evaporator and distilling plant is placed on the protective deck. There are four evaporators and four distillers, with their accessories.

The evaporators have a combined capacity of 23,000 gallons of water per 24 hours.

The distillers have a combined capacity of 23,000 gallons of potable water per 24 hours.

The evaporators take steam from the auxiliary steam pipe, and the coil drain pipes lead through a by-pass, automatic traps, to the feed tanks. The evaporator-feed and fresh-water pump takes steam from the evaporator coils, as well as from the auxiliary steam pipe.

The shells of the evaporators have connections with valves and pipes for directing the steam into the distillers and into the auxiliary exhaust pipe.

The feed water for the evaporators is taken from the circulating pipe, after it has passed from the sea and through the distillers.

There are blow pipes of ample size, so arranged that the evaporators may be blown out when working under pressure.

The distiller circulating pumps discharge to the distillers, the water passing overboard or into the sanitary system at will. There is also a direct connection from this pump to the flushing pipes, and the relief valve for the distiller is so placed as to act for both the distillers and the flushing system.

In addition to the pump connection for distiller circulating, provision is made for circulating water through the distillers, from a conveniently located discharge pipe from a pump discharging to the fire main.

A small reservoir tank, fitted with a removable cover, is placed in the fresh-water pump suction between the pump and the distillers.

A water meter, without lead, is placed in the pipe connecting the reservoir tank with the bottom of the distillers.

Evaporators.—There are four horizontal evaporators, each having three hundred and twenty square feet of tube-heating surface. The tubes are two inches outside diameter and are without bends.

The tubes are secured to the tube sheets so that adequate provision is made for expansion, and the tubes are so arranged that their removal will leave the shell accessible in all its parts for scaling. All tubes are easily removable for cleaning and repairs, and there are no internal detachable joints in the tubes.

Distillers.—There are four distillers, each having one hundred and fifteen square feet of tube-cooling surface, measured on the outside of the tubes.

The tubes are straight, $\frac{5}{8}$-inch outside diameter, tinned on both sides and well expanded and sweated into tube sheets. Provision is made for the expansion of the tubes by the use of a flange tube sheet working in a stuffing box.

FEED-WATER HEATERS.

In each engine room there is a feed-water heater with all necessary fittings complete.

The heating surface of each heater is 1,150 square feet, measured on the outside of the tubes. They are of the direct-flow type, located on the discharge side of the main feed pump.

The heating agent is the auxiliary exhaust steam. The tubes are $\frac{5}{8}$-inch outside diameter, No. 16 B.W.G.

PUMPS.

The pumps are in accordance with the table on the following page.

PUMPS.

Auxiliary.	Number.	Type, make and location.	Steam cylinders.					Water cylinders.			
			Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.	Constant "K" (mean of both ends).	Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.
Main air pumps.	2	Cameron, twin, vertical bucket, single-acting, one in each engine room.	2	14	2¼	18	.00686	2	35	3½	18
Main circ. pumps.	2	Centrifugal, driven by compound engine, one in each engine room.	2	H.P., 11 L.P., 22	2½	10	.00235 .00955	...	...	...	...
Main feed pumps.	4	Cameron, vertical piston, double-acting, single, two in each engine room.	1	16	2¾	18	.009	1	10	3	18
Aux. feed pumps.	4	Cameron, vertical piston, double-acting, single, one in each starboard fireroom.	1	12	2½	12	.00337	1	8	2½	12
Reserve feed-water pump.	1	Cameron, vertical piston, double-acting, single, starboard engine room.	1	5	1	6	.00029	1	6	1	6
Fire and bilge pumps.	6	Cameron, vertical piston, double-acting, single, one in each engine room.	1	12	2½	12	.00337	1	10	2½	12
		One in each port fireroom.	1	10	1¾	12	.00234	1	8	2	12
Auxiliary condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1½	12	.00084	1	10	1½	12
Dynamo condenser pumps.	2	Cameron, combined horizontal piston, single, one in each engine room.	1	6	1½	12	.00084	1	10	1½	12
Evaporat. and distill. plant.	2	Evaporating feed pump, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	2	Distilling fresh-water pumps, Cameron, vertical piston, double-acting, single, evaporating rooms.	1	3½	¾	4	.00028	1	4	¾	4
	1	Distilling circulating pump, Cameron, horizontal piston, double-acting, single, starboard evaporating room.	1	12	2½	12	.00337	1	14	2½	12
Ice machine.	1	Distilling circulating pump, centrifugal, driven by de Laval st. turbine, port evaporating room.	...	...	...	...	...	...	...	...	...
	2	Allen dense-air, H. B. Roelker, berth deck, starboard, forward.	1	9¾	1¾	13	.00242	...	...	...	...

PUMPS AND PUMP CONNECTIONS.

No.	Pumps.	Size, inches.	Kind.	Suction pipes from—		Discharge pipes to—		Location.
				In.		*In.*		
2	Main air	2 14-inch, 2 35-inch, by 18.	Twin, vertical bucket, single acting.	13	Condenser	11	Main feed tanks	One in each engine room.
2	Main circulat'g.	Centrifugal	Vertical compound.	21	Sea	21	Condenser	One in each engine room.
				15½	Main drain	21	Overboard.	
4	Main feed	16 by 10 by 18	Ver. piston, double-acting, single.	5	Feed-tank connecting pipe	5	Main-feed discharge main	Two in each engine room.
				5	*Channel ways	5	*Main feed tanks.	
4	Fireroom feed	12 by 8 by 12	Ver. piston, double-acting, single.	3	Bottom blows in athwartship compartments.	4	Auxiliary feed main	One in each starboard boiler room.
				3½	*C. and R. pipes from ship's sides	3½	*Main feed tanks.	
				4	Feed suction pipe	3½	*Reserve feed-water tanks.	
				3½	*Reserve feed-water tanks	3	Overboard in port compartment. Fire extinguisher.	
4	Fireroom fire and bilge.	10 by 8 by 12	Ver. piston, double-acting, single.	4	Fireroom floors in starboard and port compartments.	4	Fire main	One in each port boiler room.
				4	Sea	4	Overboard in same compartment.	
				4	C. and R. drainage manifolds	2½	Hose connection.	
				1½	Hose connection.			
2	Fire and bilge	12 by 10 by 12	Ver. piston, double-acting, single.	5	Sea	5	Fire main	One in each engine room.
				5	Engine-room bilge	5	Overboard.	
				5	Crank pits	2½	Hose connection.	
				4½	Shaft alley.			
				1½	Hose connection.			
				5	C. and R. drainage manifolds.			
1	Res. feed water.	5 by 6 by 6	Ver. piston, double-acting, single.	3	Reserve feed-water tanks	2½	Feed-tank connecting pipe. Reserve feed-water tanks.	Stbd. engine room.
2	Shaft bilge	Capac. of each about 480 cu. in. per stroke.	Plunger, single acting.	4½	Engine-room bilges	4½	Overboard	One in each engine room.
				4½	Crank pits in same compartment.			
				4½	Shaft alley.			
2	Distiller circulating.	1 12 by 14 by 12.	Hor. piston, double-acting, single.	..	Sea	..	Distillers. Sanitary system. Fire main.	Stbd. evaporator rm.
		1 15-H.P.	Steam turbine	..		..		Port evaporator rm.
2	Auxiliary air and circulating	6 by 10 by 10 by 12.	Combined	5	Auxiliary condenser	3½	Main feed tanks	One in each engine room.
				5½	Sea	5½	Auxiliary condenser.	
2	Dynamo air and circulating.	6 by 10 by 10 by 12.	Combined	5	Dynamo condenser	3½	Main feed tanks	One for ea. dynamo rm. in engine rms.
				5½	Sea	5½	Dynamo condenser.	
2	Evaporat. feed.	3½ by 4 by 4	Light service	..	Sea Distiller circulating water discharge.	..	Evaporators	Starboard and port evaporator rooms.
2	Distiller fresh water.	3½ by 4 by 4	Vertical pist'n, light service.	..	Bottom of distillers	..	Fresh-water tanks. Main feed tanks. Reserve feed-water tanks.	Starboard and port.
2	Engine-room oil.	3½ by 2 by 4	Piston, with hand attachment.	..	Oil-storage tanks	..	Distributing tank, with overflow pipe from tank to pump suction.	One in each engine room.

*Connections on after pumps only.

WEIGHTS OF PROPELLING MACHINERY.

The contract weight of the propelling machinery and boilers was 2,060 tons, the actual weight was 2,106 tons, or 46 tons overweight. Below we find the weights in detail and the sum total.

	Pounds.
Cylinders of main engines	391,174.0
Shafting	279,008.0
Main engine framing and bearings	306.919.5
Reciprocating parts of main engines	111,629.0
Main engine valve gear	85,999.0
Main condensers	125,453.0
Main air and circulating pumps	61,782.0
Propellers	66,743.0
Boilers	1,062,971.0
Boiler fittings	391,059.6
Smoke pipes and uptakes	458,687.0
Steam and exhaust piping and valves	159,029.0
Suction and discharge piping and valves	142,148.4
Lagging and clothing	38,449.4
Flooring, gratings, etc	116,892.0
Auxiliaries	107,093.0
Fittings and gear	105,361.5
Water	369,696.0
Stores, tools and spare parts	153,222.0
Miscellaneous machinery	160,629.0
Connections under steam engineering to other miscellaneous machinery	23,664.0
Total	4,717,608.4
Total weight above, tons	2,106.075
Less :	
Contract weight, tons	2,060.0
Authorized changes, tons	2.59
Spare crank-shaft, propeller blades and evaporator spares, tons	40.190
Water in evaporators and distillers, tons (13,410)	5.986
feed and filter tanks (65,600)	29.285
Total	2,097.761
Net weight in excess of contract weight, tons	91.686

ELECTRIC PLANT.

There are two dynamo rooms, one on the starboard and one on the port side of the midship line. They are on the upper platform deck just abaft the forward engine-room bulkhead and just below the protective deck.

In each dynamo room there are three eight-pole, compound-wound 100-kilowatt generators, each of these generators being capable of delivering 800 ampères of current at 125 volts when running under full load at three hundred and fifty revolutions per minute, with a shunt current of nine ampères.

The engines are compound, inverted type, with high and low-pressure cylinders of ten and eighteen inches diameter respectively.

The crank pits of the engines are used as oil wells. Oil from these wells is pumped around the bearing surfaces by means of a plunger pump connected to an eccentric on the crank shaft; the oil is drawn through a strainer past an inlet check valve and forced past an outlet check valve to the main feed pipe; the latter has a relief valve operated by hand through which excess pressure in the lubricating system may be reduced and the excess oil allowed to run back into the well. From the main oil-feed pipe branches are run to the main bearings by means of holes in the journals connecting with holes in the rock and crank pins; the crank pins are lubricated; small pipes lead from the crank-pin bearings along the connecting rods to the wrist pins which are thus lubricated, together with the slides. Holes in the slides permit the escape of the oil to the oil wells.

Another branch from the main oil-feed pipe goes to an indicator glass through which the drip of the oil to the valve slide and the eccentrics can be seen and regulated.

To prevent oil from getting into the steam cylinders and thus back into the boilers a form of stuffing box is used; this box has brushes and is packed with asbestos, thus keeping the heavy oil out of the low-pressure cylinders.

The speed of the engine is regulated by means of a spring

governor. The steam pressure used is 150 pounds, which is regulated by means of a Leslie reducing valve.

The dynamo steam lines, one from each dynamo room, lead off from the auxiliary steam lines of the ship; between the dynamo rooms there is a cross connection, which may be used to connect one dynamo room with the steam line of the other in case of necessity.

In each engine room there is a separator and a trap for separating water from the steam and draining it off.

On the generator panel of each dynamo switchboard there are three circuit breakers, one for each machine. For each generator there are two single-pole, single-throw switches, one for power, one for lighting and a common negative, besides equalizer switches.

On the right and on the left ends of the generator panel there is a panel having two circuit breakers, one for lighting and the other for power. By throwing in these circuit breakers properly, light and power may be obtained from the generators in either the starboard or the port dynamo rooms or from both.

In the distribution rooms, which are just forward of the dynamo rooms proper, there are distribution boards, each of which has three panels, one for lighting, one for power and one for the turrets.

Each panel has a double-pole, double-throw switch, by means of which the power may be taken from either the starboard or the port dynamos. On the lighting panel there are ten double-pole, single-throw circuit switches and three double-pole circuit breakers for the searchlight circuit, besides a lighting voltmeter, lighting ammeter, a searchlight voltmeter and three searchlight ammeters. On the power panel there are twenty-six double-pole, single-throw circuit switches, twenty-one of which are in use, a voltmeter ground detector, power and turret voltmeters, a power ammeter and a turret ammeter. The third panel of this board is the turret panel, which has a switch for the forward turret-turning-

motor generator, another for the after turret-turning-motor generator, and one for ordnance power in the forward and the after turrets.

ANCHOR WINDLASS.

The anchor windlass is of the vertical type and has two vertical shafts driven by worm gearing direct from a worm located on the crank shaft of the engine, without the intervention of counter shafts or beveled gears. Each shaft carries on its upper end, above the main deck, a wildcat or locking gear complete. The arrangement is such that the wildcats can be operated together or independently of each other. The wildcats revolve in a horizontal plane, taking in each bower chain on the inboard side and the sheet chain on the outboard side of the wildcats. The vertical shafts have couplings, and the lower end is keyed and supported by steady bearings.

The wildcat is cast from the best open-hearth steel to suit the 2¾-inch cable, as manufactured by the Government.

Each wildcat is fitted with a positive locking device worked by raised cams on the periphery of the locking rim, and slotted keys operated by means of a lever. The entire operation of locking or unlocking the wildcat can be accomplished by one motion of the lever through an angle not exceeding sixty degrees.

A friction-band brake is fitted to each wildcat. The brakes have sufficient surface and ample strength in all parts to "ride by" with the windlass unlocked. Each end of the friction band is provided with a compressor, so that the bower or starboard chain can be checked when running out. The compressor is controlled by a screw hand wheel set close to the wildcat.

The windlass engine is designed for a working steam pressure of one hundred and fifty pounds per square inch, but is able to withstand the full boiler pressure.

The windlass was fully tested on the official trials of the vessel as follows:

The starboard anchor was let go in thirty-three fathoms of water and the chain veered to sixty fathoms; then the port anchor was let go and both chains veered until the starboard ninety-fathom shackle was at the hawse pipe and the port sixty-fathom shackle at the controller. The wildcats were connected, and both chains hove in simultaneously, at a uniform speed, until the port anchor was at the hawse pipe. The rate of heaving in both chains together was six fathoms in 42.6 seconds. The port anchor was at the hawse pipe in 6 minutes 52 seconds. The port wildcat was disconnected and the starboard anchor was up in 3 minutes and 42 seconds. The wildcats took the shackles and swivel without surging. There was no heating of the thrust block or worm wheels.

STEERING GEAR.

The main steering arrangement consists of a right-and-left-handed forged-steel screw, connected through bushed cast-steel driving nuts and forged-steel side links direct to the crosshead on the rudder stock. The right-and-left-handed screw proper is connected by a lug clutch to another section of shafting, which shafting connects to the steering-engine crank shaft through a pair of herring-bone gears, the large gear being provided with a sliding clutch for throwing the engine in and out of gear. By throwing out this sliding clutch the steering engine may be thrown out of gear, in which condition the hand-steering wheels in the steering-engine room may be used for steering through the screw by throwing in clutch at forward end of the screw shaft; or, by leaving both of these clutches out and throwing in clutch on hand-steering wheel shaft, the rudder may be operated through the relieving tackle direct from hand-steering wheels to crosshead.

To put the rudder from hard over to hard over through the working angle of 70 degrees requires about 18 turns of the regular hand-steering wheels forward and 10¾ turns of the trick wheel at the steering engine; requires 48 turns of the hand-steering wheels in the steering-engine room, when work-

ing through the relieving tackle; requires 20¾ revolutions of the screw shaft and 85 revolutions of the engine.

The rudder, which is of the balanced type, has an area of about 274 square feet. The main frame is a steel casting, with wrought-iron boundary frame and cross bracing of flanged plates and angles, the interior being filled with white pine and the interstices with a mixture of half pitch and half tar, the whole being covered with 17½-pound plating.

The weight of the rudder is taken on a bearing at the top of the stern casting, with a floating friction ring between the crosshead casting and the stern casting. The crosshead casting has a horizontal, circular bearing surface at its upper end for the friction-band brake, which is operated by a hand wheel on the forward side of the bulkhead No. 116¼ through a long connecting rod and a bell-crank lever.

The steering engine is a 15 × 12-inch, double-cylinder, combined hand and steam-steering engine, manufactured by Messrs. Williamson Bros. Co., of Philadelphia, Pa. It is designed for a working pressure of 150 pounds per square inch, but is capable of withstanding full boiler pressure. The steam pressure for this engine is regulated by means of a reducing valve located on the after side of bulkhead No. 79, in the port engine room.

The operation of the engine by steam may be controlled either through wire-rope transmission from the steering stations forward, or by the hand wheel on the after end of the engine.

Steering Stations Forward.—The steering stations forward are located in the communication room, conning tower and pilot house. By means of a double-jaw-type clutch the communication-room wheel may be thrown into gear and the other two thrown out, or vice versa. In using the wheel in the pilot house the conning-tower wheel may be thrown out by moving it aft on its shaft. In using the conning-tower wheel the pilot-house wheel may be thrown out by disconnecting the shafting just above the conning-tower steering standard.

All shafting, except within 12 feet of compass, is cold-rolled steel, and all gears are composition with cut teeth.

Steering wheels are arranged so that when the tops of wheels go to port the helm goes to starboard and bow goes to port.

Electric helm indicators and electric-steering telegraph transmitters are located in the communication room and pilot house.

Steering Stations Aft.—The after stations are both in the steering-engine room. One consists of the trick wheel connected directly to the operating shaft of the engine, the other consists of three large hand wheels on the same shaft, properly fitted, as described, with large clutches for steering, either through the screw shaft direct or through the relieving tackle.

The relieving tackle consists principally of rope drum, operating by the hand-steering wheels through a pair of bevel gears and a worm and worm wheel, on which is wound 1-inch-diameter wire rope, one end of rope leading out to port and one to starboard, and thence both aft over sheaves and through stuffing boxes in bulkhead No. 116¼, and operating on the side rods through one single and one double sheave on each side of ship, the standing part of all being connected by turn-buckle to special stiffener on after side of bulkhead No. 116¼.

Both the trick wheel on the engine and the large steering wheels are so arranged that when the top of the wheel goes to port the bow goes to port also.

A mechanical helm indicator is connected directly to the driving nut on the port side, and in the steering-engine room are located an electrical helm indicator and an electrical steering-telegraph indicator. Arrangement of clutches aft.

Attention is called to the fact that there is a possibility of the locking pin in the nut for engaging the locking disc with the herring-bone gear on the main shaft falling in the wrong slot. Care should therefore be exercised to be sure that this pin has fallen in the proper slot.

DESCRIPTION OF VENTILATION.

On this vessel all the compartments below the gun deck and the captain's cabin, the wardroom dining room, the armory, the bakery, the various water closets and wash rooms on the gun deck are provided with artificial ventilation.

Ventilation systems—either supply, exhaust, or both combined, but suitable to the requirements in each particular locality—are provided for the compartments in the various subdivisions of the ship, thus providing a positive circulation of air by means of electric blowers.

Arrangement.	Compartments ventilated.	Blower.			Style.	Location.			Type.
		No.	H. P.	Cap'y.		Deck.	Side.	Frame.	
1	Seamen's head.....	1	2.5	4,000	S. P.	Gun	P.	7–8	Exh.
2	Quarters and stores, for'd, fr., No. 23.	2	1.75	2,500	S. P.	Berth	S.	11	Sup.
3	Quarters and magazines, between frs. Nos. 23 and 40.	3	1.75	2,500	S. P.	Berth	S.	29–30	Sup.
		4	1.75	2,500	S. P.	Berth	P.	26–30	Sup.
		5	3.5	5,000	S. P.	Berth	S.	35–36	Sup.
		6	3.5	5,000	S. P.	Berth	P.	35–36	Sup.
4	Coal bunkers, washroom and passages between frs. Nos. 35 and 79	7	1.75	2,500	S. P.	Main	S.	46	Exh.
		8	1.75	2,500	S. P.	Main	S.	51	Exh.
		9	1.75	2,500	S. P.	Main	S.	63	Exh.
		10	1.75	2,500	S. P.	Main	S.	71–72	Exh.
5	Dynamo rooms and evaporator rooms.	11	6.50	10,000	S. P.	Gun	S.	75–76	Sup.
		12	6.50	10,000	S. P.	Gun	P.	75–76	Sup.
6	Berth and gun decks between frs. Nos. 76 and 95.	13	1.75	2,500	S. P.	Gun	S.	81–82	Sup.
		14	1.75	2,500	S. P.	Gun	P.	81–82	Sup.
		15	.4	600	C. S.	Gun	S.	89–90	Exh.
		16	.4	600	C. S.	Gun	P.	89–90	Exh.
7	Engine rooms.....	17	7.5	12,000	S. P.	Gun	S.	91	Sup.
		18	7.5	12,000	S. P.	Gun	P.	91	Sup.
8	Quarters, stores and magazines between frs. Nos. 93 and 105.	19	1.75	2,500	S. P.	Gun	S.	90–91	Sup.
		20	1.75	2,500	S. P.	Berth	P.	98–99	Sup.
		21	1.75	2,500	S. P.	Berth	S.	98–99	Sup.
9	Quarters and stores aft fr. No. 105.	23	2.5	4,000	S. P.	Berth	C.	122	Sup.
10	Steering engine room.	22	1.75	2,500	S. P.	S. En. room	S.	114	Sup.

All estimates for changing air in the different compartments are based on the gross volume of the compartments.

In the preceding table the capacities of the blowers are given in cubic feet per minute at one-ounce pressure. S. P. is steel-plate blower and C. S. is cast-shell blower.

VENTILATION SYSTEM.

The air is renewed in the various spaces approximately as follows:

Officers' quarters and crew space, berth deck outside of armor bulkheads, in from ten to twelve minutes.

Officers' quarters and crew space, berth deck inside of armor bulkheads, in about four minutes.

Water closets and crews' head in two to four minutes.

Wash rooms one to three minutes.

Store rooms and passages in six to eleven minutes.

Magazines in from six to eight minutes.

Engine rooms and steering compartments in about three minutes.

Evaporator rooms in about two minutes.

Dynamo rooms in about three-fourths of a minute.

This ventilation is provided by twenty-two electrically-driven fans, manufactured by the B. F. Sturtevant Company, Boston, Mass. Size, type and location given in table above.

None of the principal longitudinal or transversed watertight bulkheads of the ship have been pierced by the ventilation ducts where possible to avoid it. No ducts have been carried through the transversed slopes of the protective deck, but in all cases through the flat and fore-and-aft slopes. Where ducts pass through protective deck they are made watertight to the highest practical point above the berth deck. All ducts passing through the magazines are galvanized-steel seamless tubing or built of heavy-gauge steel worked watertight. A natural exhaust duct, equal to the area of mechanical supply duct, has been provided for each magazine and located as far as practicable from supply duct. The upper ends of the ducts are carried up close to the gun deck

and inside of the barbettes where practicable, and terminate there with a gooseneck, the lower end of which is bell-mouthed and covered with wire mesh.

McCerry, or equally effective adjustable elbows, fitted with butterfly dampers, have been used for supply terminals in all quarters, living spaces and elsewhere. In the quarters they are nickle-plated and in other places galvanized. All openings of these elbows are fitted with portable wire mesh. All other terminals are stationary.

All cowls have been installed where necessary for fan inlets or exhausts over bakery, galley, etc. Where any of the cowls interfere with the working of the guns or where necessary for cleaning decks they are made portable at the weather decks, and where such cowls are too high above the weather decks to be easily reached they are fitted with operating gear worked from weather decks. Where required, cowls under awning have been provided with wire-mesh screens.

The ventilation for the coal bunkers has been arranged with ducts of galvanized-steel tubing or built of heavy-gauge material. Valves and dampers have been fitted for this system, and all openings into bunkers have been covered with wire mesh to keep coal out of ducts.

Especial attention has been paid to the ventilation arrangements provided to avoid the transmission of heat from the engine and boiler rooms to other parts of the vessel. In wake of the boiler rooms an air casing under protective deck and on the inboard side of berth deck coal-bunker bulkheads has been fitted and connected to ship's ventilation for supply, and to the funnel casings for natural exhaust. The under side of protective deck within the engine rooms has been fitted with sheathing, with an air space allowed, and connected to the engine-room ventilation system for supply and to the engine-room hatches for exhaust.

For ventilating the two engine rooms there are two fans so arranged that one fan supplies the starboard engine room and the other the port. Branches have been led from the main to all working stations, platforms, air casing and corners of the rooms where required for efficient ventilation.

DRAINAGE SYSTEM.

The following is a general description of the drainage system, the features covered being as follows:

1. 15½-inch main drain.
2. 5½-inch secondary drain.
3. 4⅜-inch double-bottom drain (2 sections).
4. 4⅜-inch forward-bilge drain.
5. 4⅜-inch aft-bilge drain.
6. 4⅛-inch independent drain. F. R. (Bu. S. E.) eight of them.
7. 5-inch independent drain, E. R. (Bu. S. E.) two of them.

Main Drain.—This is 15½ inches diameter throughout its entire length. It is located on the starboard side close to the center line and extends from midway of forward fireroom to forward end of engine room, where it branches and runs athwartships, each branch connecting to a centrifugal pump.

A 15½-inch stop-check valve is located in each fire and engine room, those in the starboard fire and engine rooms being in and forming part of main system; the valve in port fire rooms being connected through center-line bulkhead to the line in starboard firerooms. All these 15½-inch stop-check valves are operated at the valves and also in central ammunition passage.

In both engine rooms, at frame 75, there is a 5-inch connection between the main drain and the C. & R. manifold numbers 6 and 7 located at frames 78 and 79. This manifold is connected to the fire and bilge pumps in the fire and engine rooms.

Secondary Drain.—This is 5½ inches diameter throughout its entire length. It has connection to all fire and bilge pumps through the C. & R. and S. E. manifolds; also to the handy-billy pump manifold located on the upper platform, forward, frames 34 and 35; aft, frames 94 and 95. The forward connection is made directly to the forward fireroom manifold, No. 1, frame 41, while the after connection is made through C. & R. manifold No. 8, located in the port engine room, frames 92 and 93.

The forward secondary drain end connects to C. & R. mani-

fold No. 1, located in forward fireroom, frame 41, and the after end to C. & R. manifold No. 8, in port engine room, frames 92 and 93.

The forward bilge drain, forward trimming-tank drain and chain-locker drains are taken by secondary drain through manifold No. 1, located in forward fireroom, frame 41.

The after bilge drain and after trimming-tank drain are also taken by secondary drain through manifold No. 8, located in port engine room, frames 92 and 93.

There is a 5½-inch connection from bilge well in each fireroom and in each engine room to the secondary drain.

Double Bottom Drain.—The double bottom drain is divided in two sections, each being 4⅝ inches diameter.

The forward section runs aft on the port side from frame 46 to frame 70 and 71 and connects to the C. & R. manifold No. 5, and drains the double-bottom spaces under the fireroom forward of frame 74. It has a connection to C. & R. manifold No. 4, located from frame 55 and 56.

The after portion of this section runs athwartships at frames 69 and 70, and drains wing double bottoms outboard of reserve-feed double bottoms.

The after section runs fore and aft from frame 74 to 89 on the starboard side, and connects with C. & R. manifold 6 and 7, frames 78 and 79; and it drains all double-bottom spaces aft of frame 74, except double bottoms used for reserve-feed tanks.

The double-bottom compartments are flooded through the S. E. manifolds connected to C. & R. manifolds operating the stop-check lift valves in their respective manifolds.

Forward Bilge Drain.—It is 4⅝-inches diameter and drains all double bottoms between 19 and 40 (double-bottom ends at frame 19) and the hold compartments between frames 9 and 19. It connects to C. & R. manifold No. 1, located in forward port firerooms, frames 41, and is drained from there through the secondary drain.

After Bilge Drain.—It is 4⅝-inch diameter and drains all double-bottom compartments between frames 92 and 105 (double-bottom ends at frame 105) and hold compartments be-

tween frames 105 and 113. It connects to C. & R. manifold No. 8, located in port engine room, frames 92 and 93, and is drained from there through secondary drain.

Independent Drain.—These drains come under the cognizance of the Bureau of Steam Engineering. In the firerooms they are 4 inches in diameter and run from the bilge wells to to the fire and bilge pump. These drains are fitted in each fireroom.

The independent drains in engine room are 5 inches in diameter and come under the cognizance of the Bureau of Steam Engineering. They are fitted in each engine room, and drain the bilge wells and shaft alley and engine room. The draining of the shaft alley is to the engine-room bilges, from where there is a direct connection to the Bureau of Steam Engineering manifold, which is connected to the fire and bilge pump.

C. & R. MANIFOLDS.

No.	Frame.	Port or starboard.	Where.
1	41-42	P.	No. 2 fireroom.
2	47	P.	No. 2 fireroom.
3	63	P.	No. 6 fireroom.
4	55	P.	No. 4 fireroom.
5	70-71	P.	No. 8 fireroom.
6	78-79	P.	Port engine room.
7	78-79	S.	Starboard engine room.
8	92-93	P.	Port engine room.
9	97-98	P.	Port engine room.
10	106	P.	Hold, aft.
11	34-35	P.	Upper platform, forward.
12	94-95	C. L.	Upper platform, aft.
13	21-22	S.	Hold, forward.

S. E. MANIFOLDS.

(Not numbered on ship.)

No.	Frame.	Port or starboard.	Where.
14	45-46	P.	No. 2 fireroom.
15	53-54	P.	No. 4 fireroom.
16	62-63	P.	No. 6 fireroom.
17	70-71	P.	No. 8 fireroom.
18	78-79	P.	Port engine room.

No.	Frame.	Port or starboard.	Where.
19	78	S.	Starboard engine room.
20	79-80	P.	Port engine room.
21	79-80	P.	Port engine room.

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS ABOVE W. T. LONGITUDINAL.

Compartment.	Frames.	Side.	Gallons.	Tons. F. W.	Tons. S. W.
A-93	23-28	S.	5,062	18.8	19.4
A-94	23-28	P.	5,062	18.8	19.4
A-95	28-35	S.	8,184	30.4	31.3
A-96	28-35	P.	8,184	30.4	31.3
B-63	40-44	S.	4,335	16.1	16.5
B-64	40-44	P.	4,335	16.1	16.5
B-65	44-48½	S.	5,142	19.1	19.6
B-66	44-48½	P.	5,142	19.1	19.6
B-67	48½-53	S.	5,465	20.3	20.9
B-68	48½-53	P.	5,465	20.3	20.9
B-69	53-57	S.	5,035	18.7	19.2
B-70	53-57	P.	5,035	18.7	19.2
B-71	57-61	S.	5,088	18.9	19.4
B-72	57-61	P.	5,088	18.9	19.4
B-73	61-65	S.	5,735	21.3	21.9
B-74	61-65	P.	5,735	21.3	21.9
B-75	65-70	S.	5,708	21.2	21.8
B-76	65-70	P.	5,708	21.2	21.8
B-77	70-74	S.	5,008	18.6	19.2
B-78	70-74	P.	5,008	18.6	19.2
C-86	74-79	P.	6,111	22.7	23.4
C-87	74-79	S.	6,111	22.7	23.4
C-88	79-87	P.	12,249	45.5	46.8
C-89	79-87	S.	12,249	45.5	46.8
C-90	87-93	P.	8,023	29.8	30.6
C-91	87-93	S.	8,023	29.8	30.6
D-93	93-98	S.	4,819	17.9	18.4
D-94	93-98	P.	4,819	17.9	18.4
D-95	98-100	S.	1,885	7.0	7.2
D-96	98-100	P.	1,885	7.0	7.2
Total, ...			175,698	652.6	671.2

CAPACITIES OF DOUBLE-BOTTOM COMPARTMENTS BELOW W. T. LONGITUDINALS.

Compartment.	Frames.	Side.	Gallons.	Tons. F. W.	Tons. S. W.
A-97	19-23	P. and S.	6,138	22.2	22.8
A-98	23-28	P. and S.	16,718	62.1	63.9
A-99	28-35	P. and S.	28,106	104.4	107.4
B-79	35-40	P. and S.	27,916	103.7	106.7
B-80	40-43	P and S.	16,987	63.1	64.9
B-81	43-46	P. and S.	17,794	66.1	68.0
B-82	46-48½	P. and S.	15,318	56.9	58.5
B-83	48½-51	P. and S.	15,669	58.2	59.9
B-84	51-54	P. and S.	19,168	71.2	73.2
B-85	54-57	P. and S.	19,490	72.4	74.5
B-86	57-60	P. and S.	19,652	73.0	75.1
B-87	60-63	P. and S.	19,759	73.4	75.5
B-88	63-65	P.	4,119	15.3	15.7
B-89	63-65	S.	4,119	15.3	15.7
B-90	65-70	P.	7,376	27.4	28.2
B-91	65-70	S.	7,376	27.4	28.2
B-92	70-74	P.	6,488	24.1	24.8
B-93	70-74	S.	6,488	24.1	24.8
C-92	74-79	P.	7,807	29.0	29.8
C-93	74-79	S.	7,807	29.0	29.8
C-94	. .	. .	. .	. .	. .
C-95	. .	. .	. .	. .	. .
C-96	79-82	P. and S.	15,587	57.9	59.5
C-97	82-86	P. and S.	20,137	74.8	76.9
C-98	86-89	P. and S.	14,294	53.1	54.6
C-99	89-93	P. and S.	18,091	67.2	69.1
D-97	93-98	P. and S.	22,182	82.4	84.7
D-98	98-100	P. and S.	10,756	39.9	41.1
D-99	100-105	P. and S.	19,882	74.9	76.9
Total, ...			395,224	1,468.5	1,509.2

TRIMMING TANKS—PUMPING AND DRAINAGE.

There are four trimming tanks, two forward and two aft. Those forward are flooded by 5-inch sea connection, frames 7 and 8, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch angle valve, operated at valve and on berth deck in deck plates, frame 7 and 8.

Those aft are flooded by a 5-inch sea connection, frames 114 and 115, port side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch angle valve, operated at valve on berth deck in deck plates, frame 114 and 115.

Draining.—The forward tanks are drained by a 3-inch pipe lead to manifold No. 1, frame 41, and after tanks by a 3-inch pipe lead to manifold No. 9, frame 92 and 93. The extreme forward and after tanks are sluiced into adjacent compartments.

From these manifolds, Nos. 1 and 9, water is handled by secondary drain.

MAGAZINE-FLOODING SYSTEMS.

The following is a general description of the piping of the magazine-flooding systems:

There are two systems—one forward and one aft. Each system floods the magazine spaces in the hold and on the lower platform; the upper platform systems, forward and aft, being supplied by connections to fire main.

Forward System.—It is composed of three separate systems, one on the starboard and two on the port side, each being supplied by an 8-inch sea connection between frame 21 and 22 starboard, and port 35 and 36 port.

Adjacent to the sea connections are 8-inch globe valves on the lower platform, operated at valves and on berth deck in deck plates.

The systems are run below lower platform beam, branches being led up through the deck to the valves in magazine spaces on lower platform and down to valves in hold spaces.

After System.—It is composed of two separate systems one on starboard and one on port side, each being supplied by 8-inch sea connections between starboard frame 100 and 101, and 101 and 102, port. Adjacent to the sea connections are 8-inch globe valves on lower platform, operated at valve on berth deck in deck plates.

The systems run below the lower platform beams, branches being led up through the deck to valves in magazine spaces on lower platform and down to valves in hold spaces.

Upper Platform Systems.—These are connected to the fire main, as described thereunder, and in other particulars have the characteristics of the normal flooding systems.

All magazine flood valves are gate valves, operated at valve and on berth deck in deck plates.

All pipes are of copper, sabined.

All pipe sizes are internal.

Sprinkling Systems.—A sprinkling system is fitted in spaces in hold and magazines excepting shell rooms; it consists of 2½-inch brass pipe, perforated on under side, so that each powder tank can be sprinkled, and is fitted with cut-out valves in each magazine, operated at valve and on berth deck in deck plates. It is connected with the fire system which serves the flooding system on upper platform, and all of which is shown on the plan of the sprinkling system for the forward and after magazines.

All valves are brass gate valves.

DESCRIPTION OF FIRE MAIN.

A fire main of copper, treated by the Sabin process, is worked under the protective deck, nearly the entire length of the ship. The fire main is divided into six systems, viz: starboard and port, forward and after, and forward and after magazine systems, with cut-out valves for each system.

The starboard and port systems are each six inches in diameter and run on each side of the center-line bulkhead below the central ammunition passage throughout the length

of the machinery spaces to the forward and after transverse ammunition passages on upper platform where they are cross-connected; this circuit is connected by a 4-inch riser to the fire and bilge pump in each port boiler room, and by a 5-inch riser to the fire and bilge pump in each engine room. The distiller circulating pump in starboard evaporator room on berth deck can also charge the fire main through a 6-inch connection to this circuit in each dynamo room.

In this circuit there are four valves—Nos. 71 and 72 for forward cross connection and Nos. 101 and 102 for after cross connection—and they are operated either at the valves or on the berth deck in deck plates. The other systems branch from this circuit and are taken from between the cut-out valves in the cross connections mentioned above.

Branches, varying from 2½ inches to 5 inches, depending on their use, are taken from the two systems.

In general all fire plugs are 2½ inches in diameter.

The fire main is by-passed to the flushing main on gun deck between frames 42 and 43 by a 4-inch gate valve.

Valves Nos. 110 and 111, between gun and main decks, cut out supply to ash chutes. Valves Nos. 116 and 117 on the main deck control the ash-chute flushing.

All fire and bilge pumps are protected by 3-inch angle-relief valves set to discharge at 125 pounds pressure.

A 4-inch branch from forward system between frames 13 and 14 connects with the discharge main from flushing pumps, forming a by-pass from fire main to forward flushing system. A 4-inch gate valve at fire main cuts out this by-pass and a D'Este pressure-regulating valve in by-pass at junction with flushing main reduces the fire-main pressure of 100 pounds to 35 pounds before water passes into flushing main.

A 3½-inch relief valve in fire main in crew's lavatory on gun deck, port side, between frames 14 and 15, is set to relieve at 100 pounds and discharges into water-closet trough.

A 2½-inch branch from the riser at frame 112, berth deck, contains a relief valve set at 100 pounds, which discharges into scupper on the port side between frames 114 and 115.

The magazine fire systems lead to forward and after magazines on upper platform, which cannot be flooded from sea.

A 5-inch branch taken from the forward cross connection in the starboard passage on the upper platform, supplies the floods in forward magazines.

A 5-inch gate valve, No. 67, between frames 31 and 32, cuts out the forward magazine system.

A 5-inch branch taken from the after cross connection, starboard side of vestibule on upper platform at frame 94, supplies the after magazine floods.

A 5-inch gate valve, No. 103, on after side of bulkhead 94½, cuts out the after magazine system. These cut-outs, Nos. 67 and 103, are operated at valves and on berth deck in deck plates.

Fire plugs, No. 5 in forward handling room and No. 6 in after handling room on lower platforms, are supplied from forward and after magazine-flooding systems, respectively.

DECK DRAINS.

The officers' showers and baths, and firemen's and servants' washrooms on gun deck, are drained through 3-inch, 4-inch and 3-inch pipes, respectively, led up to gun-deck beams, port side near center line, and discharging overboard through ship's scuppers, at frame 46 and 47, and a special scupper, at frame 80 and 81, port and starboard.

All other plumbing spaces are fitted with independent drains, with the exception of galleys and general mess pantries, which drain through ship's scupper, frame 46 and 47, port and starboard. The crew's showers on gun deck drain into ship's scuppers, frame 12 and 13, port side only.

FRESH-WATER SYSTEM.

A fresh-water main of galvanized wrought iron, in general of 3 inches in diameter, runs the length of the ship and is supplied either by the two electric fresh-water pumps or from two 1,000-gallon gravity tanks on upper deck, the forward one at frame 41, the after one between frames 85 and 86.

Three-inch risers from the fresh-water main to forward and after gravity tanks serve as filling and discharge pipes for tanks, at frames 41 and 85, where these tanks are located. From frame 41 to 71½ this 3-inch main follows along the center line of the ship through the wash rooms on gun deck. From 71½ to 85½ it runs in the berth-deck passage and machine shop.

At frame 41 on gun deck the forward 2½-inch line turns outboard to starboard, passing through the bakery and crew's space to a point between frames 28 and 29 where it drops to berth deck. Here it follows the passage to bulkhead 20, where it passes down to protective-deck slope, runs forward to bulkhead 14, rises again and connects to filling pipe from ship's side on berth deck. This in turn is connected to pump and tanks on upper platform through a 2½-inch branch dropped near center line at frame 15.

The after 2½-inch line starts at frame 85½, in workshop on berth deck, runs aft to passage, where it turns outward to port, passing down to protective deck just forward and transverse-armored bulkhead, frame 95. From this point it follows along the protective-deck slope to frame 110, where it turns down through protective deck to upper platform and connects to pump and to tanks on lower platform and in hold.

These 2½-inch lines also serve as filling pipes to tanks, being by-passed at pump in steering-engine flat to top of tanks in hold and direct connected to top of tanks forward on upper platform.

Discharges from pumps are 2½ inches in diameter. Cut-out valves are fitted near tanks in all filling and suction pipes.

Check valves are fitted where necessary.

Suction pipes also act as equalizers. 1½-inch drain valves are fitted in suctions from tanks.

Two-inch overflow pipes are fitted to all tanks in hold; 3-inch overflow pipes are fitted to gravity tanks.

Tanks below protective deck are filled from dock or water boat through 2½-inch hose connections, starboard and port, at ship's side, under gun deck, between frames 13 and 14.

Filling pipes from ship's side, starboard and port, between frames 73 and 75, berth deck, to reserve-feed tanks are by-passed in berth-deck passage to fresh-water main, and may be used for filling tanks in hold.

Branches from the distiller line forward are arranged to fill, through two-way cocks, the copper tanks located on main deck for firemen's, petty officers' and servants' washrooms and those in laundry, these being the only rooms supplied with small tanks.

Two 2-H.P. electric pumps, having a capacity of 60 gallons per minute each, are provided for supplying the fresh-water main and filling the gravity tanks on upper deck from the tanks below protective deck. One electric pump is located on the upper platform just forward of bulkhead 19, and is arranged to draw only from forward tanks, discharging into fresh-water main and filling tanks above protective deck. The other electric pump is located in steering-engine compartment and is arranged to draw *only* from tanks aft, discharging into main and filling all other fresh-water tanks.

One and one-half-inch relief valves on pump discharges protect the pumps. The forward is set to relieve at 21 pounds pressure and after one at 26 pounds.

A 1½-inch hose valve on superstructure just above main deck, port side, frame 37, supplies steam launches with fresh water.

Branches from main supply all spaces requiring fresh water, such as lavatories, bath rooms, wash rooms, dispensary, operating room, pantries, galleys, bakery and laundry, also water butts and ice machine.

Three-quarter-inch faucets, for bucket use, are fitted in seamen's head, firemen's washroom, and for stateroom use, in athwartship passage on bulkhead 80, berth deck.

All fixtures are supplied direct from fresh-water main, except those in firemen's, petty officers' and servants' washrooms and laundry. These are supplied from cooper tanks.

All branches have cut-out valves at or near the main.

CAPACITIES OF WATER TANKS.

Compt.	Frame.	Location.	Side.	Capacity.		
				Gallons.	Tons S. W.	Tons F. W.
			FRESH WATER.			
A-31	14–19	Upper platform	Port	1,640	...	6.09
A-31	14–19	Upper platform	Starboard	1,640	...	6.09
A-31	14–19	Upper platform	Port	1,904	...	7.07
A-31	14–19	Upper platform	Starboard	1,904	...	7.07
D-4	105½–110	After hold	Both	2,804	...	10.05
D-13	105–110	Lower platform	Port	1,418	...	5.29
D-13	105–110	Lower platform	Starboard	2,708	...	10.10
D-13	105–110	Lower platform	Port	2,708	...	10.10
...	41	Upper deck	Gravity tank	990	...	3.67
...	85	Upper deck	Gravity tank	990	...	3.67
			Total, - -	18,706	...	69.65
			RESERVE FEED WATER.			
B-94	63–65½	Double bottom	Port	4,129	15.7	15.3
B-95	63–65½	Double bottom	Starboard	4,129	15.7	15.3
B-96	65½–70	Double bottom	Port	7,420	28.4	27.6
B-97	65½–70	Double bottom	Starboard	7,420	28.4	27.6
B-98	70–74	Double bottom	Port	6,493	24.8	24.1
B-99	70–74	Double bottom	Starboard	6,493	24.8	24.1
C-94	74–79	Double bottom	Port	7,764	29.6	28.8
C-95	74–79	Double bottom	Starboard	7,764	29.6	28.8
			Total, . .	51,612	197.0	191.6
			TRIMMING.			
A-1	1–5	Hold	Both	4,959	18.94	18.42
A-2	5–9	Hold	Both	4,997	19.08	18.56
D-6	113–116	Hold	Both	9,208	35.17	34.19
D-7	116–120	Hold	Both	8,228	31.43	30.56
			Total, . .	27,392	104.62	101.73

SALT-WATER SYSTEM.

A flushing main of copper, 4 inches in diameter, treated by the Sabin process, runs parallel with and close to the fresh-water main between frames 42 and 76. Branches from this portion supply the servants', firemen's and petty officers' washrooms on gun deck and laundry, galleys and general-mess pantry on main deck.

At frame 76 this reduces from 4 inches to 3 inches, and this size continues to the general workshop, where it divides into three 2-inch branches. Two of these branches turn outboard, one to starboard and the other to port, and supply salt water

to the wardroom officers' watercloset and junior and warrant officers' watercloset, respectively, on gun deck.

The third branch continues aft along the berth deck, turning outboard to starboard, and drops to the protective deck at frame 95. From this point the flushing line follows along the protective-deck slope to bulkhead 119, reducing to 1½ inches at frame 104.

This after branch supplies all the pantries and the captain's bath with salt water.

A 1½-inch riser from the main between frames 86 and 87 supplies the wardroom, junior and warrant officers' lavatories and baths on gun deck.

This flushing main is charged by the distiller circulating pumps in the evaporator rooms on berth deck, which are cross connected between frames 75 and 76. The forward and after portions of the flushing main branch from this cross connection in berth-deck passage, and are fitted with cut-out valves at their junction with the cross connection.

A 3-inch relief valve, set at 20 pounds, on cross connection in port evaporator room, protects the pumps.

A 4-inch gate valve, No. 109, between frames 42 and 43 on gun deck, permits charging the flushing main directly from the fire main.

Spaces forward of the forward transverse armored bulkhead are flushed by an independent system.

Two electric salt-water centrifugal pumps on upper platform, between frames 12 and 14, take water through a 4½-inch riser to flushing main in crew's washroom on gun deck.

This independent system supplies salt water to crew's washroom and showers, and the petty officers' watercloset on gun deck and sick-bay bath on berth deck. A 2-inch branch runs to ice machines on berth deck and supplies circulating water for compressors.

A 4-inch gate valve, No. 66, just forward of bulkhead 14 on upper platform, permits charging this flushing main from fire main when electric pumps are cut off. A D'Este pressure-

regulating valve, set at 35 pounds, in by-pass from fire main to flushing main, prevents a drop in fire-main pressure when by-pass valve No. 66 is opened.

A 3-inch relief valve in crews' head, starboard side, near bulkhead 18, set at 35 pounds, discharges into watercloset trough.

Three-quarter-inch faucets for bucket use are fitted in crew's and firemen's washrooms.

All branches taken from flushing main have cut-out valves at or near the main.

No salt-water tanks are fitted on the ship.

Two valve manifolds are on upper platform at bulkhead 35, port side, in transverse passage, and on the other on centerline at bulkhead 94 in vestibule, have connections from sea and bilge, and are designed for use with 6-inch handy-billy pump.

In addition, circulating water for ice machines is taken from a special 3-inch sea connection on lower platform, starboard side, between frames 22 and 23. The discharges overboard are through ship's scuppers.

OFFICIAL TRIALS.

The official trials of the machinery of the *Montana* consisted of three parts, as follows:

STANDARDIZATION.

For the purpose of standardizing the screws of this vessel fourteen runs were made over the standard-mile course off Rockland, Me., on April 1, 1908. The sea was moderately rough from the northward, and the wind was moderate to a fresh breeze from the north by west to north.

The mean draught of this vessel was 25 feet and $\frac{1}{2}$ inch, the trim being $7\frac{7}{8}$ inches by the stern, and the displacement was 14,537 tons.

POWER AND SPEED ON STANDARDIZATION.

Number of runs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Indicated horsepower:														
Starboard engine	4,881	4,948	4,993	8,131	8,000	8,337	13,055	12,945	12,634	13,348	13,762	10,748	10,802	10,553
Port engine	4,440	4,272	4,742	7,675	6,952	7,745	12,913	12,830	13,323	13,282	13,106	9,998	10,340	10,372
Total, both engines	9,321	9,220	9,735	15,806	14,952	16,082	25,968	25,775	25,957	26,630	26,868	20,746	21,142	20,925
Engine auxiliaries	218	215	217	249	239	252	358	432	428	444	438	405	373	373
Other auxiliaries	230	254	236	229	228	374	529	545	567	543	445	372	376	371
All machinery	9,769	9,689	10,188	16,284	15,419	16,708	26,855	26,752	26,952	27,617	27,751	21,523	21,891	21,669
Speed, knots	17.086	15.859	17.241	18.938	19.324	19.210	22.332	21.556	22.388	21.608	22.842	20.168	21.844	19.955
Mean revolutions	88.48	85.86	89.27	102.68	101.40	103.65	120.71	120 08	120.29	120.84	122.39	112.28	113.09	112.65

AUXILIARIES—REVOLUTIONS OR DOUBLE STROKES.

Number of run or observation.	Pumps, starboard.						Pumps, port.					Pumps.			
	Main air.	Main circulating.	Main feed, outboard.	Main feed, inboard.	Fire and bilge.	Auxiliary condenser.	Main air.	Main circulating.	Main feed, outboard.	Main feed, inboard.	Fire and bilge.	Distiller circulating.	Starboard dynamo condenser.	Dynamo engines.	Forced-draft blowers.
1	24	165	9	9	50	50	24	170	13	13	50	8	48	350	132
2	26	150	20	7	46	46	23	176	12	12	50	8	50	...	178
3	24	159	...	9	47	48	23	179	10	10	52	8	48	...	151
4	24	155	14	11	38	51	20	165	16	16	50	8	50	...	106
5	24	141	17	14	37	51	24	160	13	13	48	8	46	...	103
6	24	154	17	15	40	56	22	160	14	14	50	8	48	...	346
7	30	180	25	21	32	44	21	172	24	24	52	10	50	...	445
8	32	189	22	23	30	45	20	186	33	33	50	9	48	...	454
9	32	192	27	28	25	37	21	184	27	27	50	9	48	...	465
10	30	198	30	28	25	38	20	188	27	27	48	8	50	...	450
11	35	194	29	29	24	52	20	190	26	26	50	6	48	...	404
12	38	198	26	18	26	60	21	184	26	26	48	6	48	...	348
13	38	204	23	18	27	70	20	180	21	21	50	6	48	...	349
14	39	188	22	18	27	74	20	187	23	23	48	6	50	...	344

FOUR-HOUR FULL-POWER RUN.

Engine.	Revolutions per minute.	Steam pressure.			Mean effective pressure.				Cut-off in cylinders in decimal of stroke.			Vacuum, inches.	Barometer, inches.
		In boilers, per gauge.	At engine, per gauge.	H.P. steam chest gauge.	I.P. receiver, absolute.	L.P. receiver, absolute.	H.P. cylinder.	I.P. cylinder.	P.L.P. cylinder.	A.L.P. cylinder.	Referred pressure.	H.P.	I.P.	P.L.P.	A.L.P.		
Starboard.	122.93	...	262	245	113	40	106.8	51.2	21.1	21.4	54.23	86	.736	Variable	Variable	25.2	
Port	122.25	...	266	251	118	38	110.3	52.9	19.6	20.1	54.11	86	.736	Variable	Variable	25.2	
Average....	122.589	271	264	248	116	39	108.6	52.1	20.4	20.8	54.17	86	.736	Variable	Variable	25.4	

.....	Revolutions or double strokes.										Auxiliaries.	Air pressure (fire-room) in. of water.	Temperature.						
	Main air pump.	Main circulating pump.	Main feed pump.	Auxiliary feed pump.	Hotwell pump.	Sanitary pumps.	Fire and bilge pumps.	Water service pumps.	Aux. condenser pumps.	Dynamo engines.	F.D. blowers.		Injection.	Discharge.	Hotwell.	Feed.	Smoke-pipe gases.	Engine-room work level.	Fireroom work level.
Starboard.	36	187	29	...	...	...	42	...	66	350	377	1.19	38	111	76	153	605	69	76.3
Port.....	25	198	27	...	...	...	72	...	...	350	...	1.19	38	69	71	...	605	...	76.3
I.H.P	33	137	279	...	...	...	11	...	6	118	200	Total I.H.P. (auxiliaries)							791

U. S. S. MONTAN

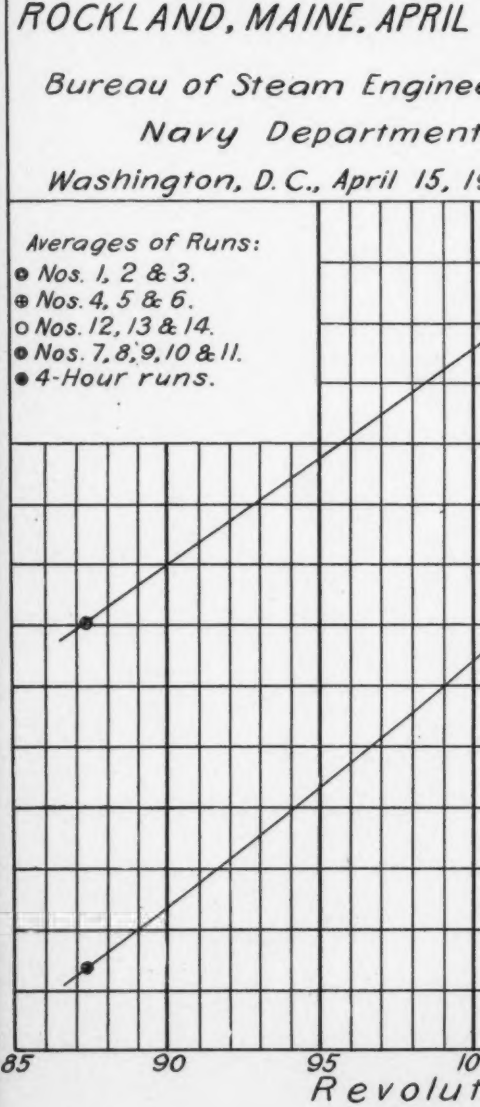
STANDARDIZATION RU

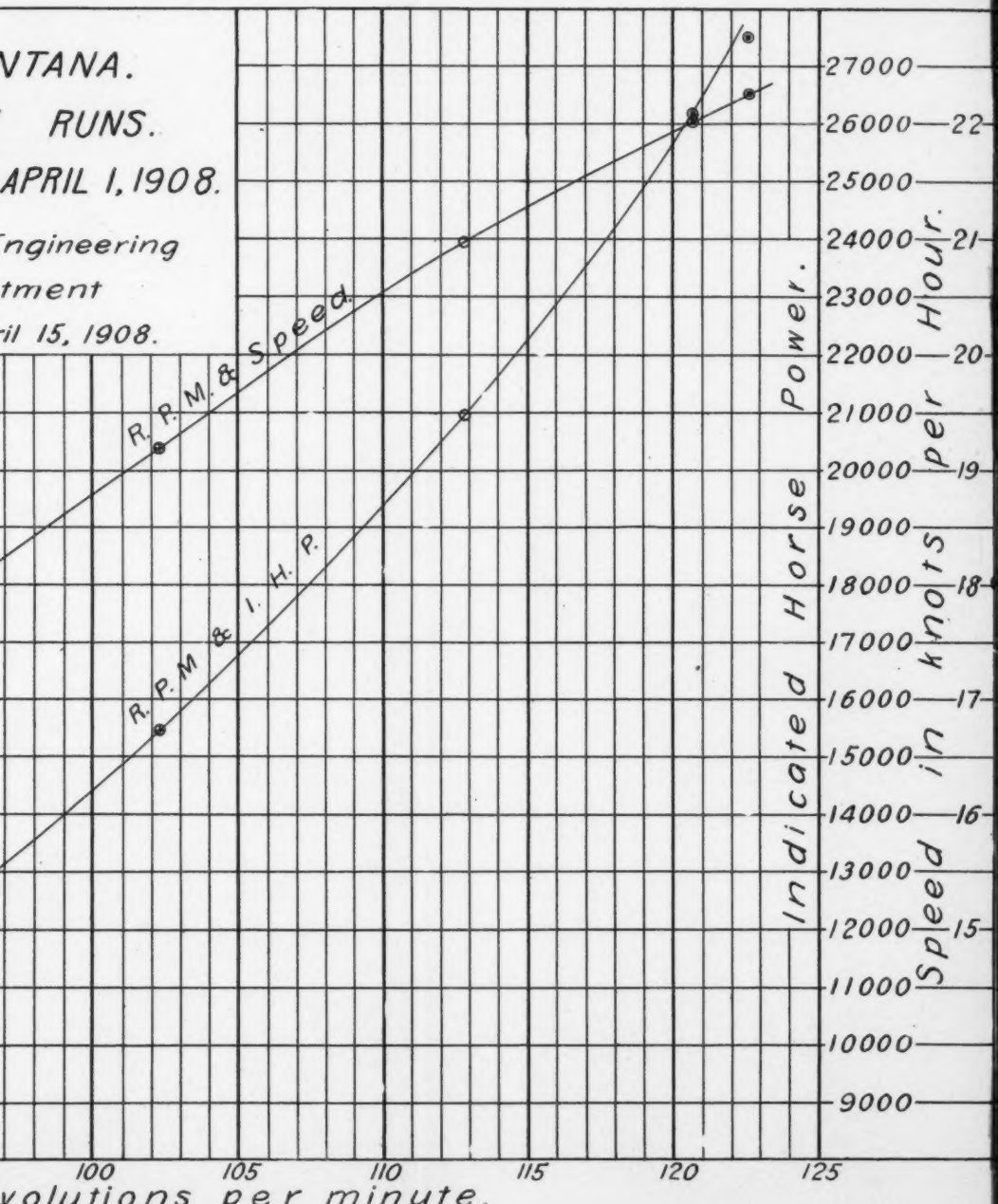
ROCKLAND, MAINE. APRIL

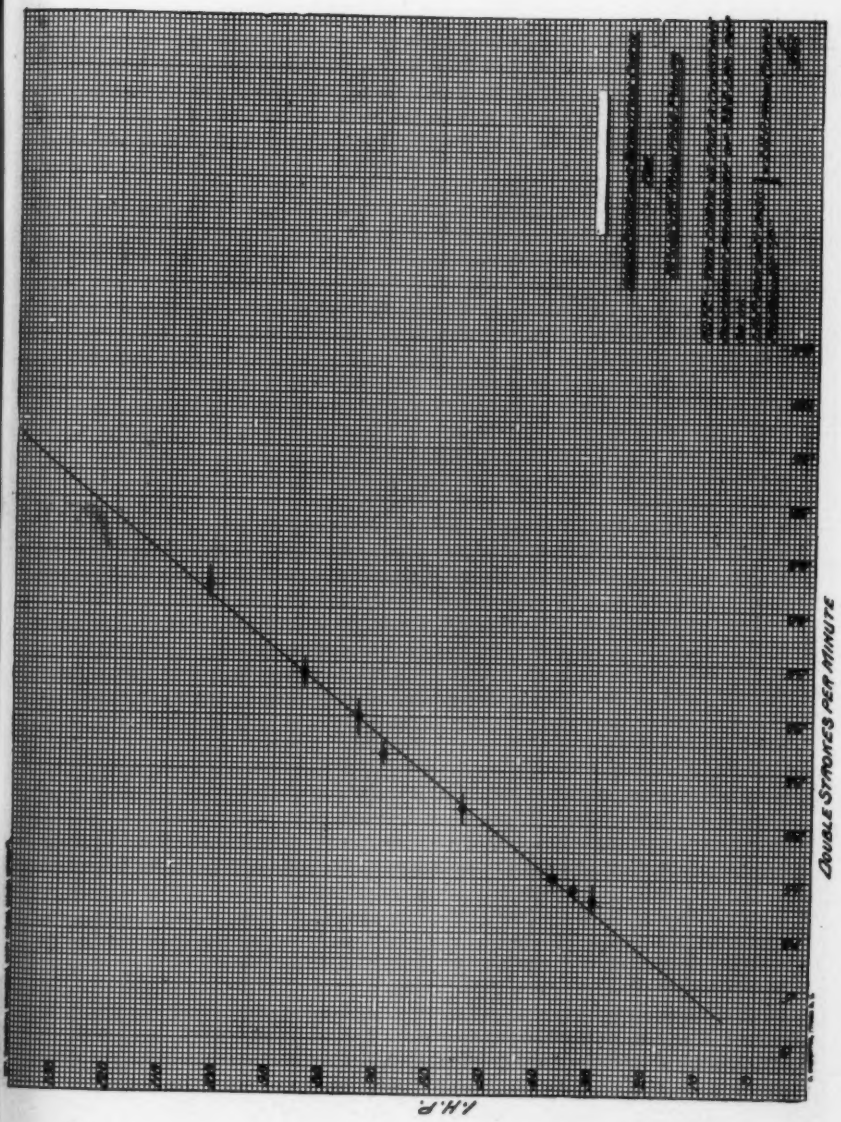
Bureau of Steam Engine

Navy Department

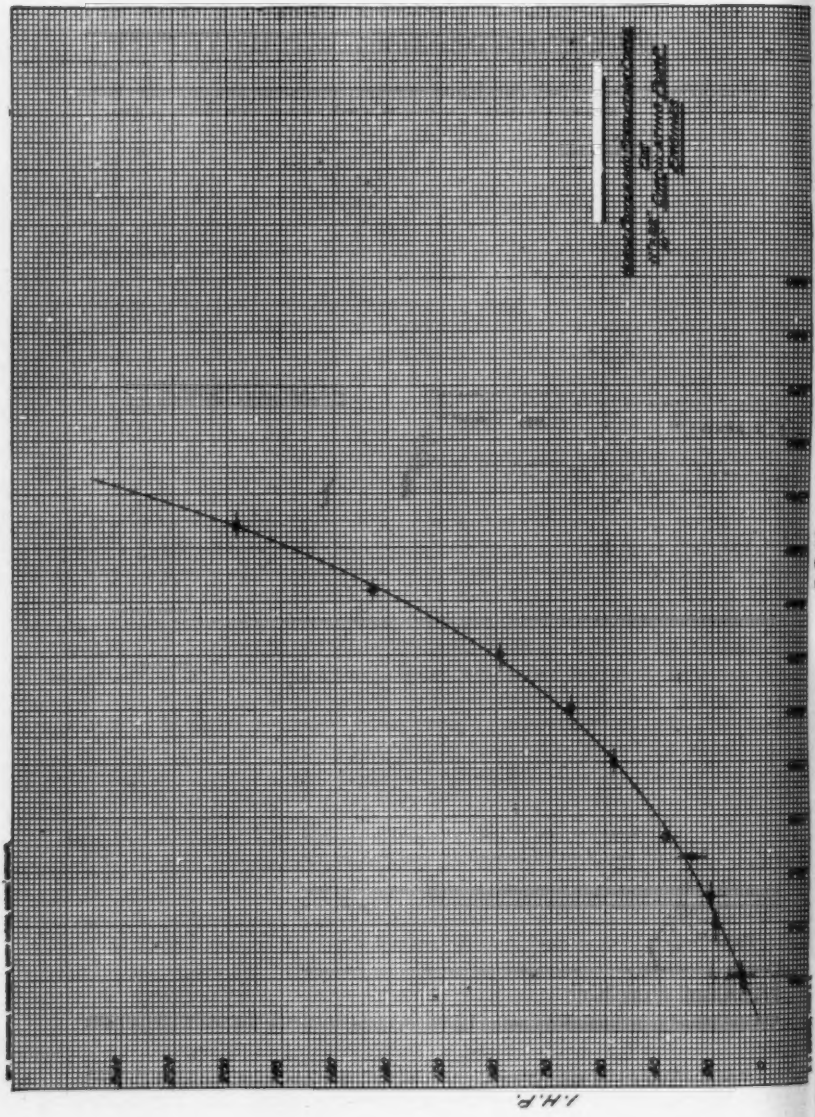
Washington, D. C., April 15, 1




NTANA.
RUNS.
APRIL 1, 1908.
Engineering
tment
ril 15, 1908.
R. P. M. & Speed.
R. P. M & I. H. P.
Indicated Horse Power.
Speed in knots per Hour.
27000
26000
25000
24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
22
21
20
19
18
17
16
15
100
105
110
115
120
125
volutions per minute.



59


I.H.P.
R.P.M.

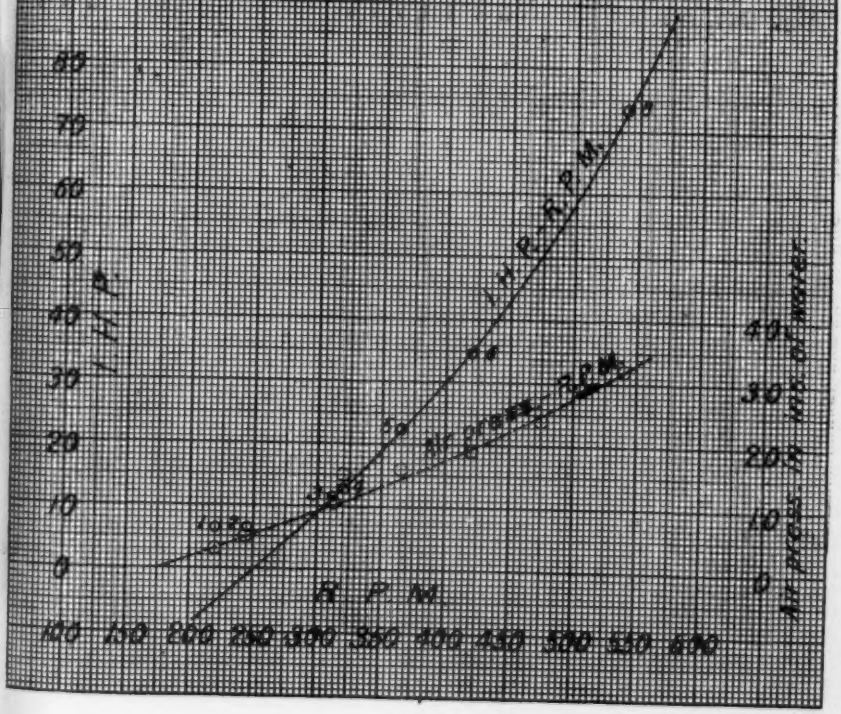
U. S. S. MONTANA

Horse Power and Revolution Curve.

Four 22½ Riker Engines

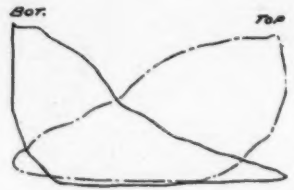
Card No.	R.P.M.	Steam Press.	M.E.P. Press.	I.H.P.
1	220	155	2.3	631
2	264	152	2.5	5.47
3	312	150	1.05	11.10
4	320	160	1.5	12.70
5	365	160	1.5	22.11
6	420	150	1.9	34.86
7	475	158	2.5	*
8	530	158	3.2	13.48

*Indicator cord broke.



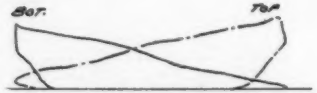
INDICATOR CARDS FROM DYNAMO ENGINES.

138.6 I.H.P. EACH, UNDER TRIAL CONDITIONS.



H.P. CYLINDER.

SCALE OF SPRING	80#
M.E.P.	61.6#
R.P.M.	340
I.H.P.	80.9
STEAM PRESSURE	150#
VACUUM	6"
VOLTS	125
AMPERES	665



L.P. CYLINDER.

SCALE OF SPRING	40#
M.E.P.	13.3#
R.P.M.	340
I.H.P.	57.7

U.S.S. MONTANA.

INDICATOR CARDS FROM ELECTRIC PLANT.

INDICATOR CARD FROM DYNAMO AIR AND CIRCULATING PUMPS.

44.6 I.H.P. EACH, UNDER TRIAL CONDITIONS.

SCALE OF SPRING	80#
M.E.P.	66.4#
DOUBLE STROKES PER MINUTE	40
I.H.P.	4.46
STEAM PRESSURE	160#
VACUUM	6"

FOUR-HOUR FULL-POWER RUN.

The four-hour full-power trial began at 6·03 P. M., April 4, 1908, and continued until 10·03 P. M. that same day. The sea was rough and the wind was a fresh breeze from northwest increasing to a moderate gale from north-northwest. The compass course steered was southwest ½ west, to south ½ west.

The mean draught of the ship was 25 feet and $\frac{7}{16}$ inch, the trim being 1⅝ inches by the stern, and the displacement being 14,531 tons.

DATA OF FOUR-HOUR FULL-POWER FORCED-DRAFT PRELIMINARY TRIAL.

	Starboard.	*Port.*
Maximum average revolutions per minute for fifteen-minute period	124.40	123.93
Average revolutions per minute, four hours	122.93	122.25
Mean revolutions per minute, both engines	122.589	
Maximum steam pressure at boilers, in pounds	275.7	
Average steam pressure at boilers, in pounds	271.0	
engines, in pounds	262.0	266.0
H.P. steam chest	245.0	251.0
Maximum air pressure in fireroom	1.47	
Average air pressure in fireroom	1.19	
Maximum vacuum, each engine	25.5	25.8
Average vacuum, each engine	25.2	25.5
Collective I.H.P. of all main engines	27,489.0	
main engine, air, circulating, feed and hotwell pumps	27,938.0	
main and all auxiliary engines in operation during trial	28,280.0	
Kind and quality of coal used on trial	Nuttleberg hand-picked.	
Average pounds of coal used during trial, per hour	57,792.0	
Pounds of coal per hour used by main and all auxiliary engines in operation during trial, per I.H.P.	2.044	
Pounds of coal used per hour by main engines, air, circulating, feed and hotwell pumps, per square foot grate surface	36.35	
Pounds of coal per hour used by main engines alone	2.102	
Draught at beginning of trial, forward, feet and inches	25–01½	
aft, feet and inches	25–02¾	
Mean draught at beginning of trial, feet and inches	25–01$\frac{13}{16}$	
Corresponding displacement at mean draught at beginning of trial, tons	14,615.0	
Draught at end of trial, forward, feet and inches	24–07½	
aft, feet and inches	25–03¾	

	Starboard.		*Port.*
Mean draught at end of trial, anchor down, feet and inches		24–11¼	
Mean draught at end of trial, anchor up, feet and inches		24–11½	
Corresponding displacement at mean draught at end of trial, tons		14,475.0	
Corresponding displacement at mean draught during trial, tons		14,531.0	
Speed of ship, in knots per hour		22.26	
Slip of propellers in percentum of their own speed	15.72		15.25

TWENTY-FOUR-HOUR TRIAL.

The twenty-four-hour trial, which was run at two-thirds power, began at noon on April 5, 1908, and finished at noon on April 6, 1908. The sea was smooth to moderate, the wind being gentle to fresh breezes from northwest to south. Various courses were steered.

The mean draught of the ship was 24 feet 1 inch, the trim being 14⅝ inches by the stern, and the displacement was 14,458 tons.

DATA OF TWENTY-FOUR-HOUR FULL-POWER FORCED-DRAFT PRELIMINARY TRIAL.

	Starboard.		*Port.*
Maximum average revolutions per minute for one-hour period	113.45		113.37
Average revolutions per minute, twenty-four hours	109.90		109.74
Mean revolutions per minute, both engines		109.82	
Maximum steam pressure at boilers, in pounds		271.0	
Average steam pressure at boilers, in pounds		248.0	
engines, in pounds	240.0		237.0
H.P. steam chest	204.0		211.0
Maximum air pressure in fireroom		0.79	
Average air pressure in fireroom		0.55	
Maximum vacuum, each engine	26.4		25.8
Average vacuum, each engine	26.0		25.4
Collective I.H.P. of all main engines		19,102.0	
Collective, main engine, air, circulating, feed and hot-well pumps		19,427.0	
Collective, main and all auxiliary engines in operation during trial		19,688.0	
Kind and quality of coal used on trial		Nuttleberg hand-picked	
Average pounds of coal used per hour during trial		36,950.0	
Pounds of coal per hour used by main and all auxiliary engines in operation during trial, per I.H.P.		1.877	

	Starboard.	*Port.*
Pounds of coal per hour used by main engines, air, circulating, feed and hotwell pumps, per square foot grate surface	23.24	
Pounds of coal per hour used by main engines alone	1.934	
Draught at beginning of trial, forward, feet and inches	24-6½	
aft, feet and inches	25-8½	
Mean draught at beginning of trial, feet and inches	25-01 7/16	
Corresponding displacement at mean draught at beginning of trial tons*	14,597.0	
Draught at end of trial, forward, feet and inches †	24-00½	
aft, feet and inches †	25-05½	
Mean draught at end of trial, feet and inches †	24-09	
Corresponding displacement at mean draught at end of trial (actual), tons	14,210.0	
Corresponding displacement at mean draught during trial, tons	14,458.0	
Speed of ship, in knots per hour	13.75	13.26
Slip of propellers, in percentum of their own speed	20.48	

The working of the machinery, both main and auxiliary, and the performance during the standardization, the four-hours full-power forced-draft, and the twenty-four-hours endurance trials, was satisfactory with the exception of minor defects, such as the unsatisfactory working of throttle valves and the defective and leaky tube in boiler N, and two defective and leaky tubes in boiler Q.

In running the five high-speed runs on the standardization trials, with the maximum pressure in high-pressure steam chest as allowed, it was found necessary, in order to obtain the contract speed of 22 knots, to by-pass live steam into the first and second receivers, as it was not possible to obtain the required speed with all steam passing through high-pressure cylinder swith the valves as set.

The contractors finding that, on the five high-speed runs of the standardization trial with boilers and machinery working satisfactorily, they could only obtain a slight margin of speed above the contract requirement with the high-pressure valves as set and live steam into the receivers, requested the Department to grant them permission to reset the high-pressure

* 109 tons of water ballast added after reading draught.

† Water brackish; density measured by hydrometer.

Engines.	Revolutions per minute.	Steam pressure.			Mean effective pressure.				Cut-off in cylinders, in decimal of stroke.			Vacuum, inches.	Barometer, inches.
		In boilers, per gauge.	At engine, per gauge.	In H.P. steam chest, gauge.	I.P. receiver, absolute.	L.P. receiver, absolute.	H.P. cylinder.	I.P. cylinder.	F.L.P. cylinder.	A.L.P. cylinder.	Referred pressure.	H.P.	I.P.	F.L.P.	A.L.P.		
Starboard..	109.90	...	240	204	88.6	34.4	92.4	36.35	17.90	17.10	42.87	.756	.725	.608	.608	26.0	...
Port.....	109.74	...	237	211	90.0	31.2	92.5	38.60	14.70	15.72	41.75	.....	...Variable ...	.....	.....	25.4	...
Average....	109.82	248	239	207	89.3	32.8	92.4	37.48	16.30	16.41	42.31	.....	...Variable ...	.....	.....	25.7	...

...	Auxiliaries. Revolutions or double strokes.										Air pressure (fireroom), inches water.	Temperature.					
	Main air pump.	Main circulating pump.	Main feed pump.	Auxiliary feed pumps.	Hotwell pumps.	Distributing circ. pumps.	Fire and bilge pumps.	Water service pumps.	Aux. cond. pumps.	Dynamo engines.	F.D. blowers.		Injection.	Discharge.	Hotwell.	Feed.	Outside air.	Engine-room work level.	Fireroom work level.
Starboard..	24.0	163.8	20.7	...	...	75	55.9	...	57.6	...	...	.55	42	100	72	168	55	73	84
Port.....	22.8	160.7	21.7	...	...	75	64.7	...	44.6	344	287	.55	42	95	65	...	55	73	84
I.H.P.....	25.0	83.0	21.7	...	...	3	18.0	...	11.0	118	80	Total I.H.P. (auxiliaries) 586							

valves so that all steam could be passed through the high-pressure cylinder, in this way economizing steam and securing a better distribution of power among the different cylinders. This request was granted, and during the four-hours and twenty-four-hours trials all steam that was used in the engines was passed through the high-pressure valves.

It was very noticeable that the engines worked more smoothly and satisfactorily when passing all steam through the high-pressure cylinders than when live steam was introduced into the receivers direct, and the power was much more equally distributed.

It was the opinion that with the machinery and boilers located in compartments isolated by athwartship bulkheads in which there are no doors for communication, it would be very difficult to maintain a proper supervision of the routine work and repairs while in port and a proper supervision of the machinery in the compartments while steaming at sea during protracted cruising, especially in peace times, when the complement of men allowed the vessel is small in comparison to what it would be during a war period.

The doors that the contractors considered necessary and that the Department allowed them to install in the athwartship watertight bulkheads for use in case of emergency, were kept sealed during the trials, with the exception of the two short periods of time on the twenty-four-hours trial, in which a tube burst in boiler N and two burst in boiler Q. At these short periods, of only a few minutes each, the seal placed on the door leading from the forward end of the engine room on the port side to the after port fireroom was broken in order to allow a communication from the port engine room to the after port fireroom.

The contractors installed two 2-inch temporary pipes from the main steam pipes to the first and second receivers, which were used only during the standardization trials for admitting live steam to the receivers. These were used in lieu of the larger by-pass pipes as originally installed.

During none of the trials was water used on any of the bearings other than that ordinarily used through the bearings.

During the twenty-four-hours trial at not less than two-thirds of the indicated horsepower as developed by main engines (and near the end of the trial), one 2-inch tube split in boiler N and two 2-inch tubes in boiler Q, the defect occurring in each case in the first pass. An examination of the defective tubes showed that there was a split in each due to laminations in the tube material, and that the lamination extended through the entire length of the tube. To facilitate the removal of the defective tube in boiler N, and because there was considerable bulge at the point of rupture, a tube in which there was no defect was removed.

An examination of the interior of the good tube removed, showed in spots excessive deposits of hard mill scale.

INSPECTION AFTER TRIAL.

a. Removed all main valves of main engines, examined valves and rings and found same in good condition.

b. Examined all main cylinders and found same in good condition.

c. Raised followers and examined all rings of main pistons.

d. Stripped P.I.O. and P.F.L.P., S.I.P. and S.F.L.P. crossheads and found caps and bearings in good condition.

e. Lifted P., Nos. 2 and 4, and S., Nos. 1, 5 and 6, crank-shaft caps and found caps and bearings in good condition.

f. Stripped S.F.L.P. and S.I.P. and P.H.P. and F.A.L.P. crank pins and found same in good condition.

g. Opened main and auxiliary condensers and filled fresh-water side with water. There was no leakage of tubes, and everything was satisfactory as far as could be examined, with the exception of a small amount of grease contained in shell of condenser. It is recommended that the condensers be cleaned before vessel is delivered to Government.

h. Examined steam and water ends and valve-chest chambers of main feed pumps and found same in good condition.

i. Examined steam and water ends and valve-chest chambers of main air pumps and found same in good condition.

j. Opened steam cylinders of circulating-pump engine and found same in good condition.

k. Examined steam and water cylinders and valve-chest chambers of one fire and bilge pump and found same in good condition.

l. Removed section of main steam pipe in No. 2 starboard fireroom. Pipe was entirely free from grease and in good condition.

m. Stripped blower in No. 3 fireroom for examination and found same in good condition.

n. Examined steam and water ends and valve-chest chambers of one auxiliary feed pump in firerooms and found same in good condition.

Boilers.—Examined interiors of drums, furnaces and fittings, interior of a number of 4-inch and 2-inch tubes selected at random, and also inboard sideboxes of all boilers except K and M. Boiler K was in use for auxiliary purposes; M was being prepared to raise steam; both of the latter boilers were thoroughly examined a few days prior to the inspection of the Board by the Inspector of Machinery at contractors' works.

Furnaces.—The furnaces were found in good condition except all brick work, furnace doors, liners and cheek pieces.

The 4-inch tubes above furnaces were straight-edged and found generally to bow upward. The maximum bend was about one-half inch from horizontal; usually the greatest bend did not exceed five-sixteenths of an inch; a few of the tubes were straight.

Drums.—The interior of drums was free from grease and scale, and inside fittings were in good condition.

Tubes.—The interior of the tubes (both 4-inch and 2-inch) showed no evidence of grease. There was some deposit of mill scale in all tubes, and as well in sideboxes.

THE TURBINE AND RECIPROCATING ENGINE A COMBINATION FOR BETTER ALL-AROUND EFFICIENCY IN VESSELS OF WAR.

By Lieut. H. C. Dinger, Member.

The question of whether the turbine or the reciprocating engine shall be installed in large fighting vessels is still argued pro and con in many services, and in the United States Navy we find the champions of both designs. There has been for some time past considerable contention between the advocates of these two systems of propulsion, and the claims of each type are being ardently set forth from time to time.

Each type of machine presents certain great advantages on one hand and certain defects on the other. The turbine gives greater economy at high speed, slight decrease in weight, does not require as much height of engine-room space, but generally requires as much or even greater floor space. Reversing presents considerable difficulties in that special arrangements and a series of backing turbines must be provided.

For slow speeds at reduced power the marine turbine is not economical, not nearly as economical as the reciprocating engine. By fitting special cruising turbines, a considerable improvement in economy is secured, but even with these added fittings the steam consumption at low speeds is unsatisfactory. A battleship will do but a very small percentage of her steaming at high speed. Ninety per cent. of the steaming will be at speeds not above 12 knots, and with this condition present, economy at these reduced powers should be a most weighty factor in deciding upon the type of machinery.

The reciprocating engine is easily handled, reversing is

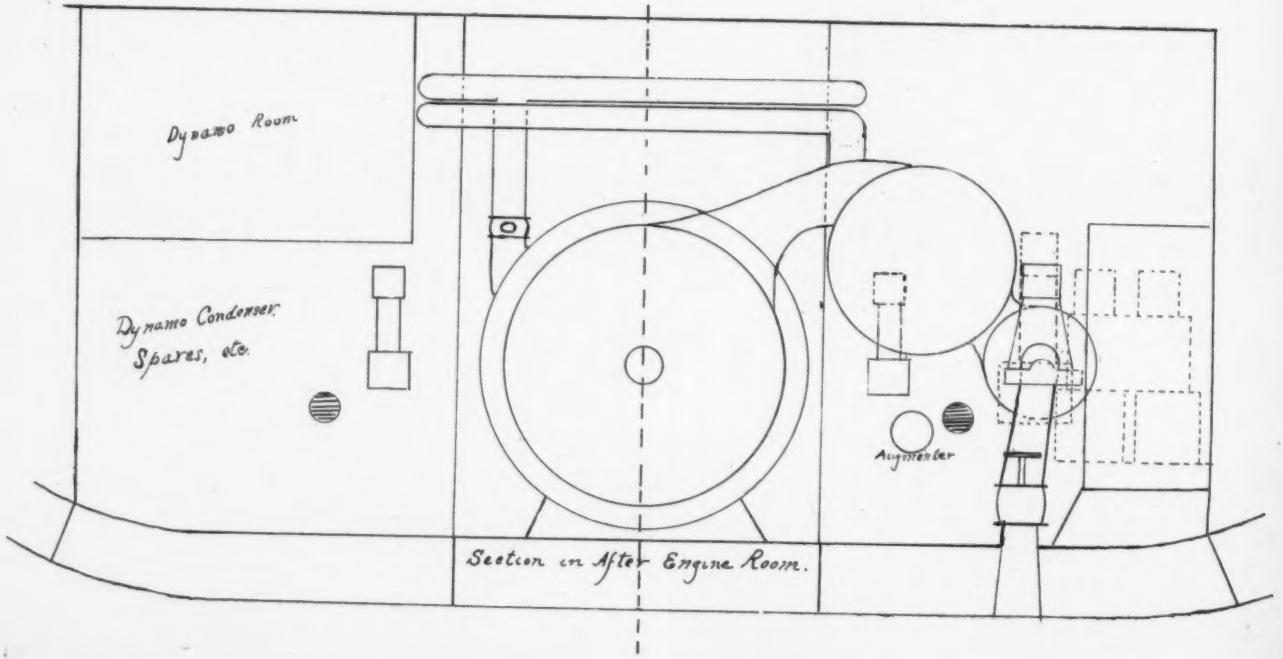
readily accomplished. It is economical at low powers, is well known and understood and is thoroughly reliable. It gives greater propeller efficiency at practically all speeds. At high speeds it is not quite as economical as the turbine. It requires more oil and attendance and is probably somewhat heavier than the turbine.

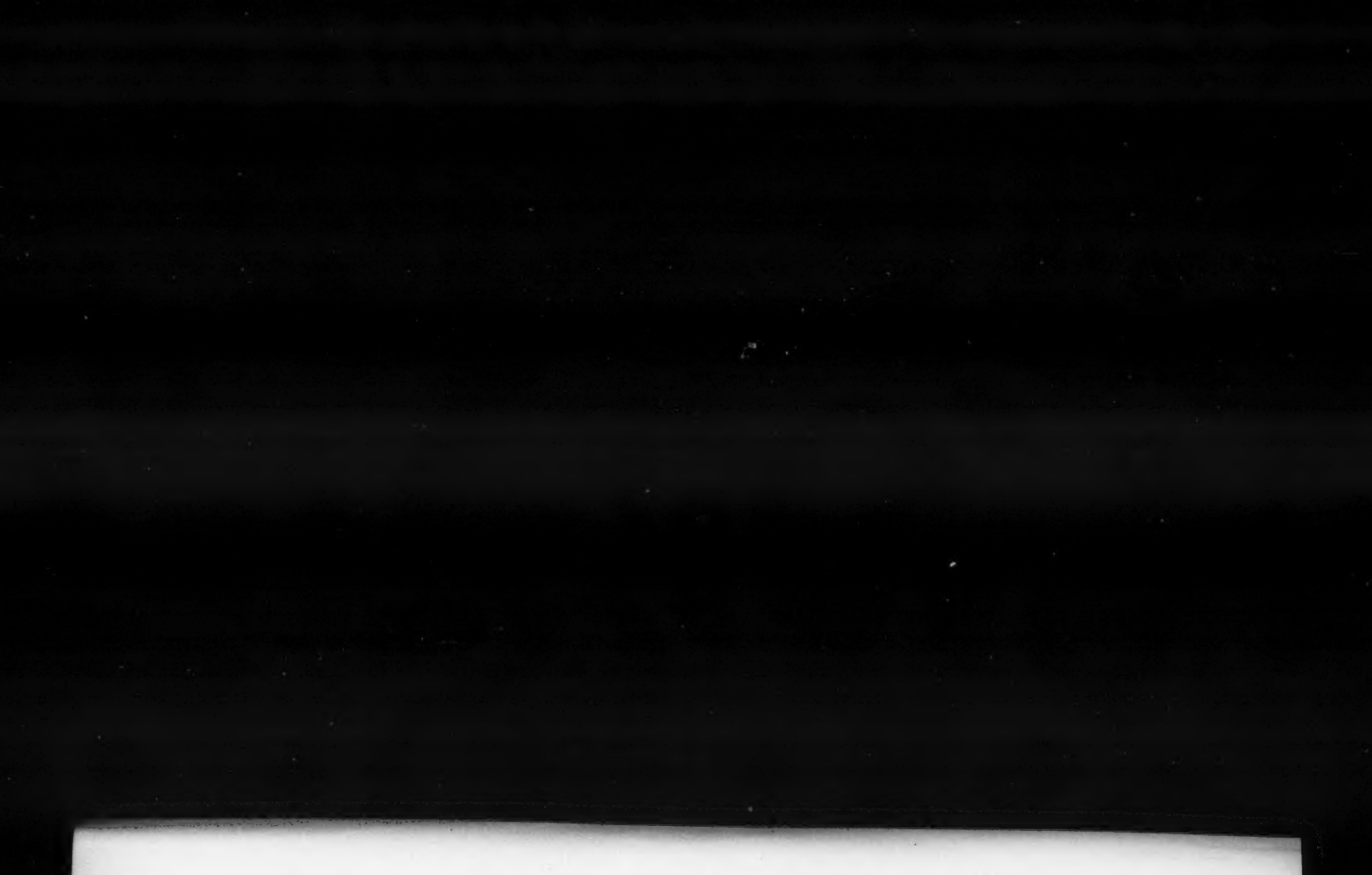
One of the prime requisites of a battleship is ability to maneuver. Anything that detracts from this important feature must be looked upon with more or less suspicion. With turbines the ship cannot be maneuvered as readily or as directly as it can when fitted with reciprocating engines. Some types of turbines are much better than others in this respect, but they are all well behind the reciprocating engine when it comes to handling a vessel at close quarters, stopping, turning, backing, etc.

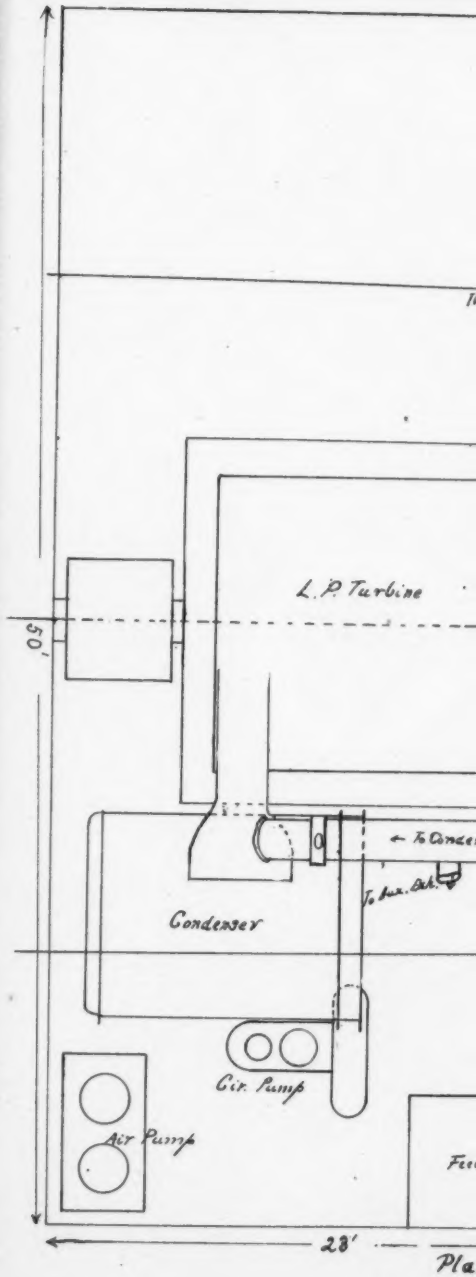
Now for one condition, cruising speeds, the reciprocating engine is better, and for another condition, full speed, the turbine is the better. But the machinery of a man-of-war must meet both of the conditions satisfactorily. Can a combination be effected that will allow us to use the advantages of each in its place? Let us see.

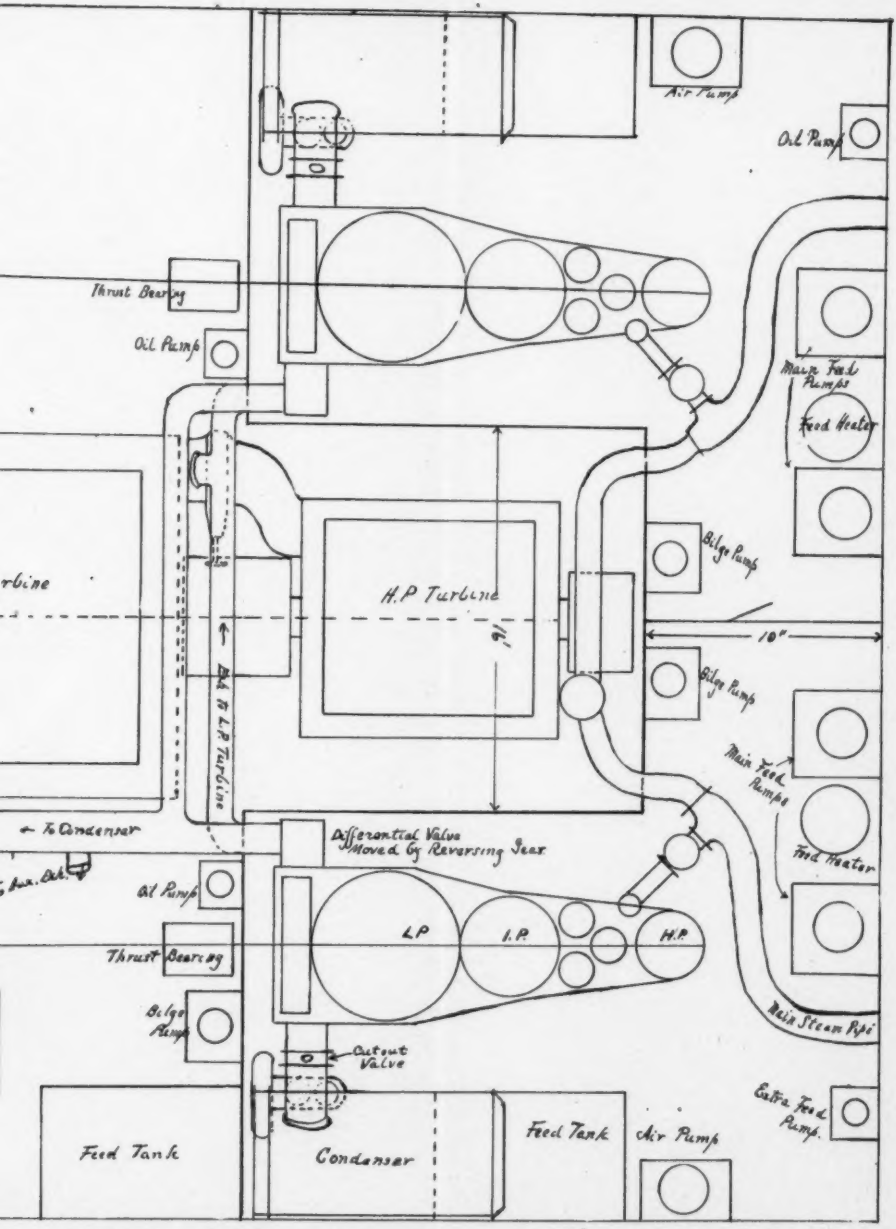
Let us propose to put the total power of a first-class battleship, 20,000 I.H.P., into three units, one on each of three shafts. The center shaft to have a turbine engine of about 12,000 I.H.P. and each of the wing shafts to have a reciprocating engine of about 4,000 I.H.P.

The general arrangement, using the same space as is now used for twin-screw reciprocating engine, will be approximately as shown in sketch. The weight will be about the same for the same total power, perhaps somewhat less than either the all-turbine or the all-reciprocating engine arrangement (for reasons spoken of later.) The reciprocating engines are to have 4,000 I.H.P. each, and would be of the latest design of three cylinder, triple-expansion type; about $\frac{22 \times 34 \times 62 \text{ inches}}{48 \text{ inches}}$. The engine should be fitted for forced lubrication, and by having this would be placed more nearly


Dynamo Room
Dynamo Condenser
Spares, etc
Augmenter
Section in After Engine Room.




L.P. Turbine
50'
Condenser
Cir. Pump
Air Pump
28'



Plan of Engine Rooms

on a par with the turbine in the matter of care in operation. They would be used alone in all cases where the speed is not over about 14 knots, which speed would require about 7,000 I.H.P. The reciprocating engines would be placed in two engine rooms, as shown in sketch. The turbine would be fitted to the center shaft; it would be fitted for going ahead only, and primarily designed for the conditions of full power. The propeller for the turbine would be designed especially for full speed, and in this condition could give better results than one designed to operate at various speeds. The propellers of the reciprocating engine might be designed to operate at their greatest efficiency at medium speeds. At very low speeds the propeller of the center shaft could be uncoupled and allowed to revolve. The loss from this drag would be very slight. It would not even be necessary to uncouple the turbine, since the whole rotor could be allowed to revolve idly. Whatever loss would be due to the revolving of this idle screw would be more than made up by the increased efficiency of the reciprocating engine and its propeller.

The turbine on the center shaft could be designed and installed to meet the conditions of going ahead only. There would be no need of any arrangements of backing or cruising turbines and the weight of these appendages would be saved. There would also be no need of trying to adjust the design to get economy with the turbine at low and greatly varying powers. Thus, further reductions of weight might be possible. The turbine shaft, being in the center, will give the greatest possible room for installing a rotor of large diameter. The whole combination allows for a very compact arrangement, as can be seen from the sketch.

Though the exact space required would depend on just what design of turbine was used, it would be possible in practically all types to place the turbine directly between the ends of the reciprocating engines, as shown in sketch. By doing this considerable fore-and-aft space is saved. The location of the auxiliaries is indicated in a general way and

the suggested arrangement gives fully as ample room as that available in our latest design using reciprocating engines. The space is 50 feet in length and 50 feet in width, and this is considerable less in length than what has been used for the same purposes in the twin-screw reciprocating-engine arrangement for 16,500 I.H.P. In the *Connecticut* design a length of about 60 feet is used, though this includes some bunker space. If the same length, 60 feet, is used there will be correspondingly more room for the combination arrangement. On the *Delaware* class, with 25,000 I.H.P. and all-turbine arrangement, a space 51 feet athwartship and 60 feet in length is to be used.

ADVANTAGES SECURED.

If it is assumed that the turbine gives an increase of 10 per cent. in economy over the reciprocating engine at full speed (an assumption less than the turbine advocates claim and somewhat more than the turbine has, as yet, done in practice) we would, in the proposed arrangement, have an increase in economy of 6 per cent. over the reciprocating arrangement at full speed. At one-fourth or one-third power, which would be the cruising speed of the vessel, the turbine, as now developed with cruising turbines and other refinements, may be assumed to use 30 per cent. more steam than the reciprocating engine (the difference is very likely to be even greater than this). So on this basis the combination arrangement, using the reciprocating engines and with the turbines revolving idly, would give about 30 per cent. greater economy than the all-turbine arrangement at cruising speeds.

At cruising speeds, 12 to 14 knots, one-fourth to one-third power will be required. This will be equal to three-fifths to three-fourths of the power of the reciprocating engines proposed. It also is the point at which these engines work at their greatest economy. At this point the reciprocating engine will be about 5 to 10 per cent. more economical than when operating at one-third to one-fourth power, the condition met with the twin-screw reciprocating engine at cruising

speed. Therefore the proposed combination would give an advantage of 5 to 10 per cent. in economy, at cruising speeds, over the all-reciprocating engine using two engines.

Summing up, then, the following will be accomplished by the combination when using the turbine entirely independent of the reciprocating engines:

1. An increase of about 30 per cent. in economy over the all-turbine arrangement at cruising speeds.

2. An increase of 5 to 10 per cent. in economy over the twin-screw reciprocating-engine design at cruising speed.

3. An increase of about 6 per cent. in economy over the twin-screw reciprocating-engine design at full speed.

4. A decrease of about 4 per cent. in economy over the all-turbine arrangement at full speed.

5. About the same space and weight will be needed as for the twin-screw reciprocating design or for the all-turbine three or four-screw design. Everything, however, points to a considerable saving in both weight and space by the adoption of the combination.

6. Less space and weight will be needed than for the three-screw reciprocating design.

7. Increased reliability over the all-turbine arrangement would be secured. Four-tenths power for either ahead or backing is given by a thoroughly reliable and familiar machine.

8. As great, and probably greater, reliability is obtained than with the twin-screw reciprocating-engine design.

9. Greater efficiency for the propellers can be obtained for both full speed and cruising speed. The turbine propeller can be designed without special regard to very low speeds, and the reciprocating-engine propellers can be designed to give their best effect at near cruising speeds. When going at high speeds the propellers of the reciprocating engine would be working at a slightly decreased efficiency.

10. Full four-tenths backing power can be secured exactly as with the present reciprocating-engine design.

11. Smaller engine compartments can be used, and hence

greater chances of stability should one of the compartments become damaged.

Such a combination may be slightly modified and a still greater economy at cruising speeds obtained. This is accomplished by operating the reciprocating engine and the turbine as a combination in series.

The proposition of a combination of reciprocating engines and turbines has recently been the subject of articles by Hon. C. A. Parsons and R. J. Walker in the "Transactions of British Institution of Naval Architects," 1908. This proposition is there specially confined to merchant vessels of moderate speed, 16 knots and below. The *Laurentie* now building for the White Star Line has this combination feature.

The same reasons that would make such a combination desirable for a merchant vessel will hold for a battleship or other man-of-war where moderate speeds are largely used. A battleship should not be considered a race horse; her province is to fight, not to reconnoiter or to run.

In this installation the boiler steam is admitted into the reciprocating engines and exhausted from them (at from 20 to 7 pounds absolute) to the turbine, which carries on the expansion; finally exhausting into the condenser with a vacuum of 28 inches.

By this combination the power will be about equally divided between the reciprocating engine and the turbine when the initial pressure at turbine is about 15 pounds absolute. By this combination it is claimed, and fairly-well substantiated by reliable data, that a steam consumption of about 12 pounds of water per I.H.P. can be obtained, a result beating by about 20 per cent. the best results of either all-turbine or all-reciprocating marine-engine installation.

This economy is effected owing to the fact that the turbine can use the lower ranges of expansion much more efficiently than can the reciprocating engine, and conversely the reciprocating engine can, and does, use the higher ranges at reduced powers more efficiently; so that by the combination each system uses the steam at the point and under the conditions where it can handle it most efficaciously.

In the system proposed for a battleship, it is designed that at full power the turbine and the reciprocating engines shall act independently, each taking steam at boiler pressure and exhausting into its own condenser. But at reduced power (below two-thirds power) the two systems are to work in combination, the reciprocating engine exhausting into the L.P. turbine. In this way the machinery plant will give its maximum economy in steam consumption at the cruising speed. With the all-turbine arrangement the greatest economy is at full speed, and at any considerable reduction the economy drops materially.

By using the reciprocating engine and turbine in series a far greater efficiency in steam can be obtained at reduced speed than by either the turbine or the reciprocating engine separately. The reciprocating engine will utilize the higher ranges of pressure and the turbine will use the lower range. In either case the engine will use the steam in a most efficient manner, and in a more efficient manner than if either type of engine used the whole range.

In this combination it is proposed to have for the L.P. cylinder of the reciprocating engine (besides the regular exhaust into its own condenser) an alternate exhaust leading to the L.P. turbine and also to the turbine condenser by another pipe. This would be arranged so that when operating in series with the turbine and going ahead the exhaust steam from reciprocating engine would pass through this exhaust and lead by means of a pipe to a valve at L.P. turbine. If the reciprocating engine is backed a connection from the reversing gear would operate a differential valve which would shut off exhaust from the L.P. turbine and throw it open to the turbine condenser. The operation of reversing when thus running in series would present no difficulty whatever, and while running combined the turbine condenser would handle all the exhaust steam and the condenser of the reciprocating engine could be shut down.

At very low power it might prove to be more economical to shut steam off the turbine altogether and run with the re-

ciprocating engines alone. This would be a matter to be determined by actual practice.

In this installation it is contemplated that the turbine be in two parts, a high pressure and a low pressure, and the exhaust from the reciprocating engine would be led to the throttle on steam chest of the L.P. turbine.

When running in series the H.P. turbine would simply revolve either in vacuum by drain connections to condenser or at atmospheric pressure.

The exhaust being led to L.P. turbine will cause this turbine to be operated at somewhere near its most efficient speed when the pressure of steam at this point is approximately at that of the atmosphere.

Using the reciprocating engines in combination with the turbine at from one-fourth to three-fifths power an economy of water consumption of about 12 to 13 pounds of water per I.H.P. can be obtained.

With triple-expansion engines this result at the above power would be about 16 pounds of water.

With turbines the above result will be about 18 to 20 pounds of water.

The combination, therefore, for cruising speeds has the advantage of 15 to 25 per cent. in economy over the all-reciprocating engine arrangement, and the advantage of 25 to 35 per cent. over the all-turbine installation.

As this installation has not yet been made definite or exact, results cannot be stated, but from what we now know of the operation of the reciprocating engine and of the turbine at reduced speeds, and the surprising economy of such combinations on some land engines, sufficient data is at hand to show that the combination can be made to secure a decidedly better all-around service economy than either the all-reciprocating or the all-turbine arrangement produces.

By the installation of the combination not a single advantage of the reciprocating engine is lost. The disadvantages of the turbine are overcome and its advantages are retained.

Both weight and space are saved to a slight extent.

Smaller engine-room compartments can be used, thereby improving the watertight subdivision and increasing stability.

The running economy is enormously increased.

Full maneuvering ability is secured.

The only possible point of disadvantage is a slight reduction in economy at full speed.

The point of complication may, perhaps, be raised against the proposed arrangement, but in point of fact it is much simpler than an all-turbine design when, besides the main turbines, there are separate cruising turbines and backing turbines. These extra turbines, with their piping, cause a very considerable and objectionable complication.

In the proposed plan as shown in sketch, another simplification is proposed in that there would be no auxiliary condenser installed, the condensers for the reciprocating engines being arranged to take care of the auxiliary exhaust drains, etc., both in port and when underway.

With this combination an accident to the turbine would not disable the ship or her ability to maneuver. The turbine could be repaired at leisure and the vessel still kept in condition for steaming at nearly half power during the time repairs were being made.

CONCLUSIONS.

In summing up the advantages and disadvantages, the arrangement suggested, either using the engines separately or in series, seems to present a much greater all-around efficiency and economy than either the all-turbine or the all-reciprocating engine arrangement does. It is suggested as something well worth investigating and trying for use in moderate-speed men-of-war, colliers or transports. The all-turbine arrangement will be quite unsatisfactory in economy at cruising speeds and for maneuvering purposes, so if we wish to try and realize some of the great benefits that turbines have, this appears to be a way in which they may be realized to a large extent without sacrificing the economy and reliability at cruising speeds, which the reciprocating engine undoubtedly has.

SUBMARINE NAVAL WARFARE.*

By G. Laurenti, Major Constructor, Royal Italian Navy.

Until recently the principal means for coast defense consisted of artillery and of submarine mines. The development of submarine mines indicated that artillery was not considered sufficient in itself to resist the assaults of an energetic enemy, but that it should be supplemented by the provision of obstacles and concealed dangers. At the present time, however, fixed mines are considered of minor importance, principally because of the deterioration of the electric cables connecting them to the shore. Apart from the rulings of the Hague Conference, the use of mechanical contact mines may be considered as a partial means of offense, since they act to blockade a squadron within a harbor, or may be employed to make a bay impracticable. They are, however, undesirable as weapons of defense for a military port, since they are dangerous to any vessel crossing their lines, and their recovery is difficult after the termination of hostilities; besides which they are liable to be displaced by currents, and thus become dangerous to neutrals. Floating torpedoes are found unreliable in service, owing to the rapid deterioration of their delicate mechanism, and hence recent efforts have been directed toward the perfection of the submarine boat. Such boats, controllable beneath the surface of the water, according to the movements of the enemy, and carrying on board a number of torpedoes ready for service, now constitute the most effective means for operating successfully against an opponent. The submarine boat may be considered as the arm of ambush *par excellence,* and although

* Reprinted from "Cassier's Magazine," Nov., 1908.

in France and England Fulton's early plans for submarine warfare were condemned as savoring of piracy, yet at the present time such methods are considered as entirely legitimate, as leading to success in naval warfare.

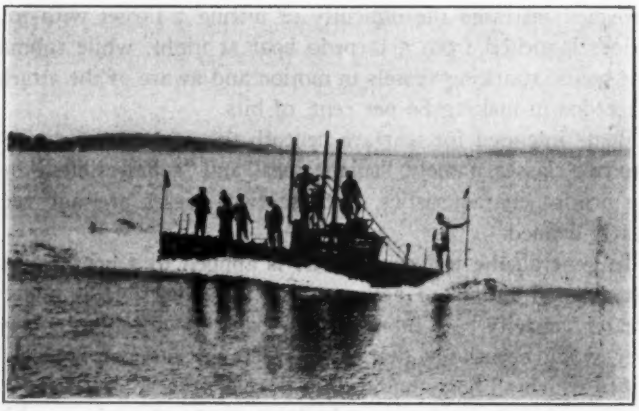
The torpedo boat was designed originally as a vessel for attack by surprise, but an experience of nearly twenty-five years has shown that this method is of very limited value. It is folly for a torpedo boat to attack a prepared enemy in broad daylight, while at night it is most difficult to determine the distance and direction of vessels in motion. Recent British trials have demonstrated the difficulty of hitting a target with torpedoes launched from a torpedo boat at night, while submarine boats, attacking vessels in motion and aware of the attack, succeeded in making 80 per cent. of hits.

Boats intended for warfare beneath the surface are divided into two classes, namely, "submarines" and "submersibles," but the precise characteristics of these two classes are not very clearly defined.

In general, the term submarine is applied to a boat having but a small radius of action, while a submersible is one of greater capacity. A more correct basis of difference, however, would seem to be that of the reserve of buoyancy, according to which all boats having but a small reserve, say from 10 to 15 per cent., or less, might be termed submarines, while those with a larger reserve of buoyancy would come under the classification of submersibles. A small reserve of buoyancy renders a boat little adapted for long voyages at the surface, and hence it is unnecessary to arrange such vessels for a large radius of action, whilst those included under the classification of submersibles, having a larger portion unsubmerged, may be better equipped for a larger radius. Probably a more rational classification is that which describes all submarine torpedo boats as adapted either for coast defense or for high-sea service, corresponding somewhat to the practice obtaining with ordinary torpedo boats.

Taking into account first the form of the hull, the conditions

involved in ordinary floating operation include simply such lines as give the least resistance at the maximum required velocity, and also furnish the best nautical qualities. For a real submarine, that is, a vessel having but a short radius of action at the surface, and intended principally for operation under water, the form adapted for minimum resistance beneath the surface should be given entire attention, while for submersibles, designed for long voyages either upon or below the surface, both conditions should be carefully studied.



FRENCH SUBMARINE "GRONDIN," SHOWING DEPRESSION OF STERN WHEN UNDER WAY.

In addition to the resistance to motion, however, there must also be considered the crushing action of the external pressure. Theoretically the cigar form of hull is assumed to offer the following advantages:

1. Least resistance to motion under water.
2. Maximum resistance to crushing in proportion to weight.

The first advantage is very materially affected by the presence of superstructures necessarily attached to the hull, these also affecting the weight and requiring heavier plates than indicated by theoretical computations. In practice, therefore,

the defects of the cigar-shaped hull may be enumerated as follows:

1. Large resistance for surface navigation.
2. Tendency to depress the stern, both for surface and submarine navigation.
3. Lack of longitudinal stability in surface navigation.
4. Lack of space for the machinery, especially near the ends.

The first defect is due to the waves formed by this particular shape of hull, and for this reason a speed is soon reached at which the resistance when traveling on the surface is greater than that when moving beneath the water. The second point is really a question of dynamics, due to the fact that the water has a tendency to mount the stern and cause its depression, as is shown in the illustration of the French submarine *Grondin*. This action is modified either by the addition of superstructures, as in the British submarines, classes "B" and "C," or those of Lake and Equivilley, or by the provision of an initial depression of the bow by means of water ballast, as in the case of the American submarine *Shark*.

This tendency to depress the stern constitutes one of the principal defects of a submarine, and was first observed in the early trials of American submarines, in which it was noticed that the horizontal rudders had to be operated in order to raise the stern. This question was also made the subject of experimental investigation by Naval Constructor D. W. Taylor, in the Government testing tank at Washington.*

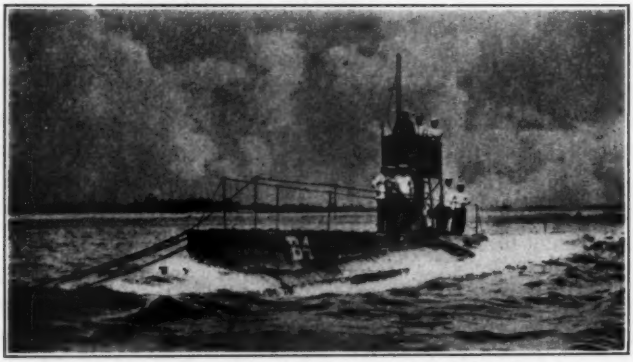
The results of these experiments fully confirmed the observations at sea. In consequence Mr. Taylor examined the behavior of a series of submarine types with vertical bow and stern and found these to give a better longitudinal equilibrium when propelled under water.

The insufficient longitudinal stability at the surface is due to the comparatively short length of immersed surface, as was well shown by Sir William White in his investigation of the loss of the submarine *"A 8."*†

* See "The Limitation of the Diving Submarine," by R. G. Skerrett, "Journal of the Royal Artillery," June, 1907.
† Report before the Royal Society, May, 1906.

This defect may be eliminated by the use of a braced superstructure, acting to lengthen the hull, but this involves an increase in weight without the addition of a corresponding transverse strength.

By reason of these defects in the cigar-shaped hull various other forms have been devised, taking into account the requirements both of surface and submarine navigation. Among these, one of the first was that used by the French engineer, Laubeuf, who, in the *Narval* (1896) adopted a mixed construction, consisting of a double hull; the outer skin being of light plates of a form adapted for surface navigation, and an inner shell with transverse bulkheads to resist the external crushing pressure. This design has advantages, so far as the external form is concerned, and gives additional strength to resist collision, but it has the defect that the space between the two hulls cannot be pumped out at great depths, because the outer shell is too light to resist the pressure.



ARRANGEMENT OF SUPERSTRUCTURES ON BRITISH SUBMARINE "B4."

Since external superstructures are considered indispensable in connection with surface navigation, it has been found possible to utilize them to aid in giving transverse strength, and to use other forms of cross-section than the circular for the hull. In the submarines designed by the author the inner and outer hulls are both used to resist the external pressure, and

the superstructure is designed so as to stiffen the upper part of the boat.

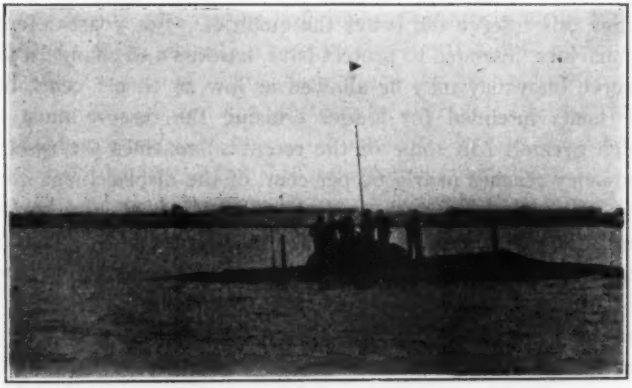
The reserve of buoyancy differs very much in boats of different designs, ranging from a minimum of 5 per cent. of the total displacement in some of the French types, about 10 per cent. in the English and American Holland boats, to 20 per cent. in the Lake boat, and 30 per cent. in the French diving boats of the Laubeuf types. The nautical qualities of the boat depend very much upon the reserve of buoyancy, and in general, the larger this reserve the better the qualities. For coast-defense submarines, intended to protect bays, harbors and channels, the reserve buoyancy may be allowed as low as 10 per cent., but for boats intended for longer cruising the reserve must be much greater. In some of the recent submarines the reserve buoyancy reaches nearly 60 per cent. of the displacement, thus approximating closely the ordinary torpedo boat, and having nearly as good nautical qualities. In the case of an ordinary vessel the two elements of stability are the reserve buoyancy and the metacentric height. For a submarine, however, it is possible to have a metacentric height suitable for surface navigation, while at the same time the reserve buoyancy may be reduced either to zero or to a minimum of not more than half a ton in either small or large boats. This means that even a small influx of water in a submarine, while beneath the surface, might prove disastrous if not immediately followed by a corresponding lightening.

It would be possible to maintain a greater reserve of buoyancy while navigating beneath the surface if a portion of the motive power were diverted to maintaining the submergence, but this would be at a sacrifice of propelling power, and hence of speed.

Since submarines must be operated under two different conditions, namely, at the surface and beneath the water, it is necessary to have two independent sets of motive-power machinery. As the permissible weight for the machinery has to be divided between the two portions, the power of each is lim-

ited, and this fact alone prevents a submarine from competing in speed with a surface vessel. A high speed, however, is not required for a submarine boat, as it is in the case of scouts or torpedo boats, in which speed is the only arm of defense.

There is at the present time no type of submarine boat combining maximum speed both on the surface of the water and when submerged, and the opinions of engineers are divided as to the relative importance of the two portions of the service.



AMERICAN SUBMARINE "SHARK," SHOWING TRIM WHEN STANDING.

As examples of recent practice we may note the Italian submersible *Glauco,* of 160 tons displacement, designed by the author, which has a speed of 14 knots at the surface and 7 knots when submerged. The latest type of American Holland boat, with a displacement of 245 tons, has a surface speed of 11.5 knots, and 10 knots when under water. There are certain limitations for subaqueous velocity which do not obtain in navigation at the surface of the water. Among these may be mentioned the effect of sudden changes of direction in the horizontal plane, also the effect of speed upon the visibility of the periscope. The photograph of the trail of a periscope shows the extent to which it is visible at a speed of 8 knots, and under such conditions it is impossible to assume that the position

of the submarne could remain unobserved. The periscope is indispensable to conduct an attack with any probability of success, and since the submarine, even at a speed of 10 knots, must necessarily be much lower than the maximum speed of a battleship, it is generally thought better by designers to make the speed below the surface secondary to the safety of the men and the secrecy and success of maneuvers.

The propelling machinery of a submarine for surface navigation is generally thermal, while the propulsion beneath the water is effected by electric power. So far there has not been developed any satisfactory type of propelling machinery adapted for both functions, although various plans have been devised with this end in view.

The surface propulsion has been effected both by steam engines and by internal-combustion motors. In addition to the submarine boats built by Nordenfelt nearly twenty-five years ago, steam power has been employed on some of the French submarines, but these plans have not been reproduced in the latest designs. In the steam-propelled submarines very light water-tube boilers were used, with kerosene as fuel, the steam being used in ordinary reciprocating engines; the steam turbine has not been applied as yet to any submarine. The advantages of steam power lie principally in the flexibility of the engine, and in the ease of reversing, but in a submarine steam is inconvenient on account of weight, space occupied, heat developed and noxious gases produced.

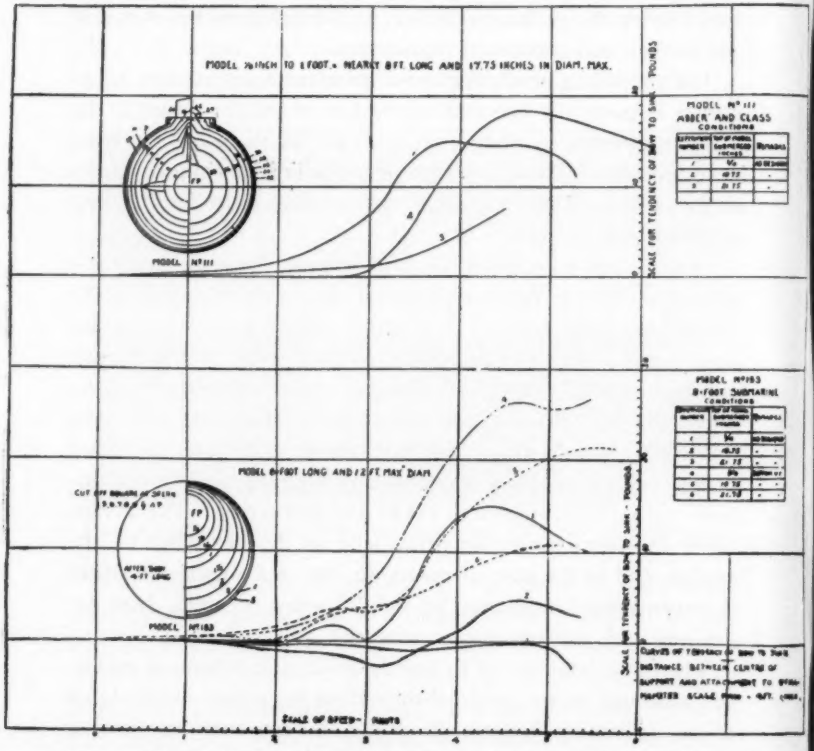
The latest tendency is to use the internal-combustion motor, and although many practical difficulties have been encountered in its application, these have nearly all been overcome during ten years' experience and effort. Combustion motors, as applied to submarines, may be classed under three heads:

1. Motors using a mixture of air and vapor of gasoline or benzine.

2. Motors using a mixture of air and vapor of lighting kerosene.

3. Motors burning heavy oils.

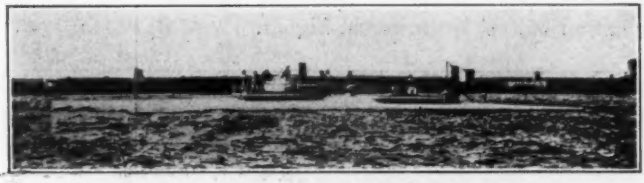
Until recently the motors of the first variety have been most extensively used. Those who have had no practical experience with gasoline motors in submarine boats have thought such machines objectionable because of the liability of formation of an explosive mixture with the air of the room, but a



EXPERIMENTAL RESULTS WITH MODELS OF SUBMARINES IN THE TESTING TANK AT WASHINGTON.

comparison of the dangers of such motors with those using kerosene will show that the first class is to be preferred to the second. The gasoline motor is more easily started, more easily installed, and is lighter and less objectionable than the kerosene engine. Any danger which might exist from the

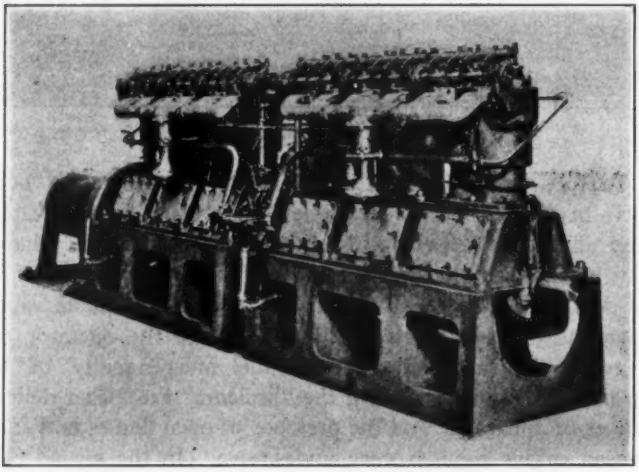
production of explosive vapors may be avoided by a proper ventilation of the engine room, and experience in a number of British submarines, involving motors up to nearly 900 horse-power, has shown no trouble from this source. The latest types using high pressures, forced lubrication and liberal water-jacketing for cylinders and exhaust pipes have proved very reliable and satisfactory.



FRENCH SUBMERSIBLE "NARVAL."

Motors using illuminating kerosene in submarine boats may be divided into two varieties, those using a flame vaporizer and those vaporizing the fuel by the heat of the exhaust. An example of the first type is the Gardner motor, used, it is said, in one of the French submarines. The flame vaporizer has the advantage of elasticity, since the operator can regulate the vaporization of the fuel independently of the operation of the engine, but the "bruleurs" are rather delicate pieces of apparatus, and the presence of open flames in a small closed engine room is very undesirable. In the second class may be noted the Koerting and the Thornycroft motors, the former being used in the submarine boats built for Germany and Russia at the Krupp yards at Kiel, while the latter has been used in two submarines built by Thornycroft for the Italian Government. The Koerting motor is of the two-cycle type, and in starting the fuel is vaporized by an electric current, and after the engine is started the heat of the exhaust gases is employed. The Thornycroft motor is a four-cycle engine and is started by benzine, the kerosene being used after the engine is well under way, and the heat of the exhaust is available. The objection to this type of motor lies in the fact

that the speed cannot be reduced below a certain number of revolutions without reducing the temperature of the exhaust to a point where the vaporization of the fuel is not properly effected. Such engines also require water injection in the cylinder in order to permit the use of a high compression without premature ignition, and unless distilled water is used the durability of the motor is apt to be affected. Such engines require more attention than the gasoline motors and the consumption of fuel is somewhat higher.



FIAT GASOLINE MOTOR OF 300 BRAKE HORSEPOWER AS ARRANGED FOR SUBMARINE.

Better results are obtained by the use of the Diesel motor, burning heavy oils, especially in connection with the two-cycle Diesel motor built by Sulzer Brothers. The first submarine in which the Diesel motor was used was the French boat *"Y,"* and some difficulties were encountered because of the conditions under which the engine had to work. In the later French submarines of the *Topaze* type and the submersibles of the *Pluviose* type, the Diesel motor of the four-cycle design has been employed with success. The two-cycle type of Diesel

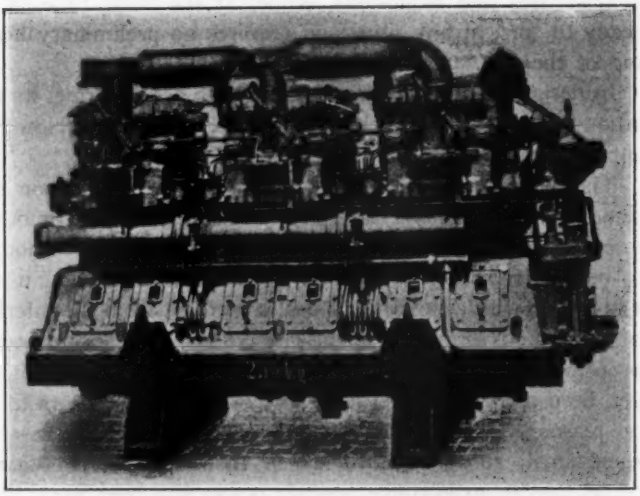
motor, however, is the latest design, and in some of the recent Diesel engines built by the Nuremberg Maschinen Fabrik, the weight has been reduced to 12 to 15 kilogrammes per effective horsepower, or about the same as a benzine four-cycle motor running at the same speed. The great advantage of the Diesel motor lies in the fact that it is able to burn all kinds of heavy oils up to a density of 0.9, thus giving the greatest security against fires and explosions, while, at the same time, it is ready to start at any time, and requires no preliminary heating of the fuel.

In designing a heat motor for use with a submarine, its relations to the electric machinery used for navigation below the surface must be considered.

The modern tendency is to arrange the two motors on the same shaft, without the interposition of any gearing or other intermediate mechanism. In order to permit the two motors to be operated, each to the best advantage, the plan of using a propeller with adjustable blades, controlled from the interior of the boat, is employed in the later submarines, the Meissner propeller being an example. Screws of this sort have not, as yet, been used above 300 horsepower, but there appears to be no reason why this should not be exceeded. In the case of some small submarines, of which the French type *Naiade* of 68 tons is an example, electric power has been used, both for the surface and submarine propulsion.

All the submarine boats now in service use electric power for propulsion beneath the surface. Some of the earlier boats, such as the *Plongeur,* of Bourgois and Brun, made in France in 1863, used compressed air both above and beneath the surface, while the Nordenfelt experiments in Sweden and in England in 1884-1885 used a steam engine for both purposes. Recently some attempts have been made to use the internal-combustion engine for motive power when submerged. In France, in 1904, the submarine "*Y*" was launched, according to the designs of Bertin, and equipped with a Diesel motor, supplied with compressed air from tanks when operating beneath the surface. Tests with this apparatus, however, did not warrant

a continuance of the system, and this boat has since been equipped with electric power for submarine service. More successful experiments have been made in Russia with the Drezwiecki system. In this case a small boat, provided with a benzine motor, was operated for more than an hour beneath the surface, and no serious inconvenience from heat or foul air was reported, but the noise was found objectionable. The

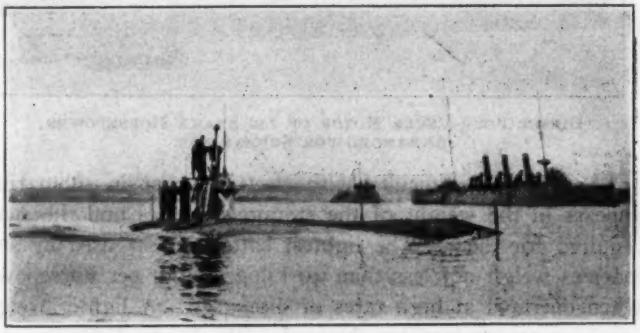


KOERTING PARAFFINE MOTOR FOR SUBMARINES, 125 BRAKE HORSEPOWER.

visibility of the exhaust discharged below the surface of the water is a defect of this system, but this is not of serious importance if the water is even slightly rough. The French engineer Sabathe has proposed to operate the Diesel motor upon a closed cycle, the engine drawing in its own exhaust gases, together with sufficient oxygen to burn the fuel charge, so that the volume of exhaust gases is greatly reduced, and the perfection of combustion would result in the production mainly of carbon anhydride, almost wholly soluble in water, and thus give an invisible exhaust.

The Italian engineer Del Proposto has devised another type

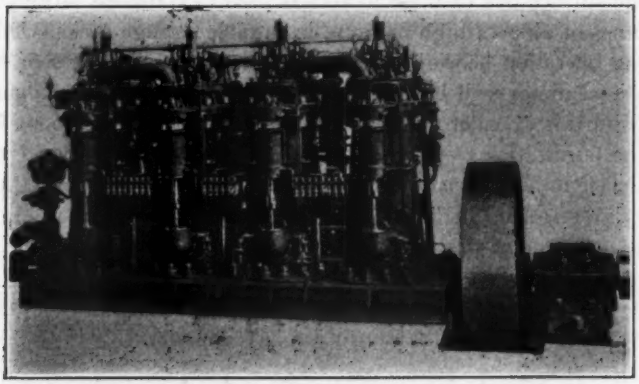
of propelling mechanism, which, it is understood, is to be installed in a large submarine soon to be built for the Russian Government. The system involves the use of two Diesel four-cycle motors with four cylinders each. During navigation on the surface one of these motors is used to compress large volumes of air to a high pressure in suitable storage tanks. During operation beneath the surface, one of the cylinders of the Diesel motor will be operated by compressed air, the exhaust from this cylinder being discharged into the engine room for the purification of its atmosphere, and also being drawn from thence into the other cylinders during the suction strokes, these cylinders operating as a combustion motor. It is practicable to proportion the parts so that an equilibrium of action may be



THE BRITISH SUBMARINE "A11," WITH NEW TYPE OF CONNING TOWER.

obtained on this principle, and at the same time obtain a greater power when navigating below the surface than when above, the two speeds thus being almost equal. When very near the surface, as when about to discharge a torpedo, any visible exhaust may be avoided by operating all the cylinders of the Diesel motor with compressed air, the exhaust being delivered into the engine room. Since it is possible for men to support a pressure of nearly four atmospheres without serious inconvenience, it would thus be practicable to operate a submarine for several miles at high speed without revealing its presence.

It is understood that it is only by the use of some form of combustion motor beneath the surface that high submarine speeds can be attained; Del Proposto expects to reach a speed of 15 miles per hour.



DIESEL FOUR-CYCLE MOTOR OF 140 BRAKE HORSEPOWER, ARRANGED FOR SUBMARINES.

The principal difficulty with electric power in submarines appears in the weight of the storage batteries and the space required for them. The lightest batteries now used by submarines weigh not less than 40 kilogrammes per horsepower when operated at high rates of discharge. A lighter weight per horsepower may be obtained with slower discharge, but the total power available will be reduced. The capacity is always limited, and it is hardly practicable to operate a submarine more than three or four hours under water at full speed. Nevertheless electric power offers many advantages for submarine use, among which may be noted the following:

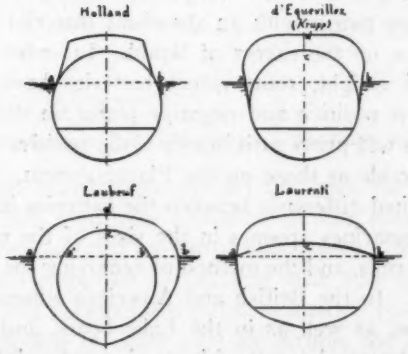
1. Uniform weight during the entire period of operation; a feature of much importance in submarine navigation.

2. Quietness during operation.

3. No heat developed, and no deterioration of the atmosphere when the apparatus is properly managed.

4. Ease of subdivision of power for the operation of motors for pumps, fans, etc.

The electric motors used in submarines are of the multipolar type, with either compound or derived windings. Except in some special instances, the motors operate at uniform speed with constant current, the variability of speed, about 15 per cent., being obtained by means of a resistance interposed in the field. For greater speed variations it is usual to vary the voltage by subdivision of the batteries; operating the sections either in series or in parallel as may be required. The minimum voltages used for operation in parallel are from 100 to 200 volts, and for series operation from 200 to 240 volts. Above 200 volts, however, it is difficult to maintain satisfactory insulation, and hence in the latest designs it is planned to maintain the voltage uniform, as 100 to 200 volts, and use motors with compensation poles, thus permitting speed variations from 1 to 1/5. This involves a somewhat greater weight for the motors, but the advantages are sufficient to permit this.



CHARACTERISTIC CROSS-SECTIONS OF SUBMARINES.

When two forms of motive power are employed, the heat motor is used to charge the batteries, and boats thus equipped are termed "autonomous" because they do not require special charging stations. The accumulators employed are generally of the ordinary sulphuric-acid type, with Faure negative plates, and either Planté or Faure positives. Batteries of the Edison type, with alkaline electrolyte, and plates of nickel salts

appeared to offer many advantages, but they have not proved satisfactory. The accumulators form an important portion of a submarine, and constitute a large part of the weight of the machinery, and when cared for with intelligence and judgment they give very satisfactory results. In the French submarines the batteries are generally of the "Fulmen" type, using d'Arsonval positive plates; the English boats use the "Chloride" type; the German and Russian are equipped with the batteries made by the Hagen Accumulatoren Fabrik; while the Italian submarines use the accumulators made by the *Societa Generale Italiana Accumulatori Eletrici,* which is a branch of the Hagen works.

In general the batteries are made with ebonite cells, some hermetically sealed, others not sealed, the acid being carried at such a level as not to be spilled by the rolling of the boat. In order to avoid inconvenience from the motion of the electrolyte in the cells, a special form of Hagen battery has been made under the Krupp patent with an absorbent material between the plates to take up the excess of liquid. In order to secure a reduction of weight, some recent batteries have been made with both the positive and negative plates on the Faure system, and this will prove satisfactory if the positive Faure plates prove as durable as those on the Planté system.

The principal difference between the batteries in the various types of submarines appears in the sizes of the elements, the shape of the cells, and the method of removing the gases which are evolved. In the British and American submarines of the Holland type, as well as in the Lake boats, and in some of the Russian boats, elements of large size and weight exceeding one ton have been used, while in the French boats the weight is about 200 kilogrammes, and in the Italian submarines about 100 kilogrammes. The object of using large elements is to obtain the greatest capacity with the least weight, but there are a number of objections to such a practice. Thus, large elements are difficult to instal, and have often to be made in several parts to permit them to be passed through the hatches; besides which it is difficult to replace damaged parts. With

large elements, also, any damage puts a considerable portion of the entire battery out of service, while the contrary is the case with smaller elements.

An important matter is the removal of the gases which are evolved from the battery, especially during the latter part of the period of discharge. As is well known, these gases consist of oxygen and hydrogen in such proportions as constitute an explosive mixture, besides being non-respirable, and a number of serious accidents have occurred by their accumulation.

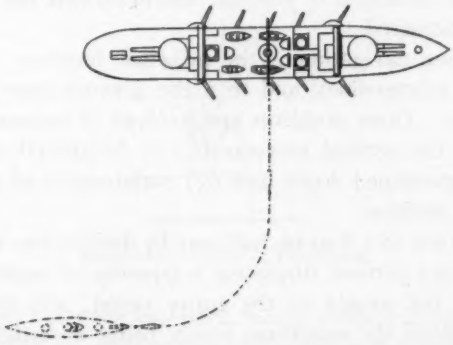


DIAGRAM ILLUSTRATING PATH TAKEN BY A TORPEDO, AUBRY SYSTEM.

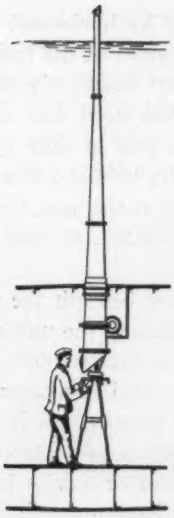
Owing to the acid vapors carried off with the gases their escape produces injurious corrosion of the machinery, and hence their removal is a matter of importance. Several methods have been employed for dealing with this difficulty. If the cells are not hermetically sealed, a method followed in the French boats, and in those built by Krupp, the gases escape into the boat and are drawn off by the use of electric exhaust fans. This plan is objectionable because the air of the boat is vitiated and because it is not possible to insure the clearing of all parts of the vessel. Another plan, used in the Holland and the Lake submarine boats, consists in enclosing the cells in a large case, from which the gases are drawn off by a ventilating fan. This is an improvement over the first method; but it is not altogether safe, as there is a possibility of the

explosive mixture in the enclosing chamber becoming ignited from a spark from the electrical apparatus. A third plan, introduced by the author in some of the Italian submarines, consists in sealing each cell airtight and providing it with a vent hole and tube, the several tubes all being combined into one collector which is exhausted to the exterior of the boat. During the charging of the battery sufficient air enters through the main collector to change the composition of the mixed gases and produce a non-explosive mixture. This system has been found successful in practice, and in no case has an explosion ever occurred.

Submarine navigation is the principal function of submarines and submersibles, and to it the greatest attention must be directed. Three problems are involved in successful operation: (1) the vertical movement; (2) horizontal navigation at a pre-determined depth, and (3) maintenance of a required stationary position.

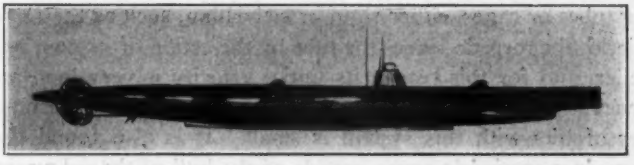
The volume of a floating hull may be divided into two parts: the immersed portion, displacing a quantity of water equal in weight to the weight of the entire vessel; and the portion which is above the waterline, which, being watertight, constitutes the reserve buoyancy. If the entire body is to be submerged it is necessary to overcome the reserve buoyancy, and this may be effected in two ways. The reserve buoyancy may consist entirely of a chamber distinct from the interior of the boat, in which case the water may be allowed to enter, simply by putting it into communication with the sea. If a portion of the reserve buoyancy is included as a part of the interior of the boat, it is necessary to increase the weight of the hull by admitting a corresponding amount of water ballast. In the diagram, sections are given of four different types of boats, and in each the reserve buoyancy is indicated by the space *a, b, d, a.*

In the Laubeuf system the submersion is effected by putting the space between the two hulls in communication with the sea, while in the other boats a double bottom is provided, the filling of which causes the vessel to sink. In the Holland and



RUSSO-LAURENTI CLEPTOSCOPE.

the Laurenti boats the superstructure is entirely above the hull, so that it fills or empties automatically as the boat sinks or rises; in the other designs the superstructures must be emptied mechanically, or by compressed air. The reserve of buoyancy may be just overcome, so that the hull weighs exactly as much as the volume of water which it displaces, or the reserve may not be entirely overbalanced, but a small amount, generally about half a ton, allowed to remain, so that the boat has a tendency to rise, or there may be an excess of ballast added, and the vessel has a tendency to sink. The horizontal path



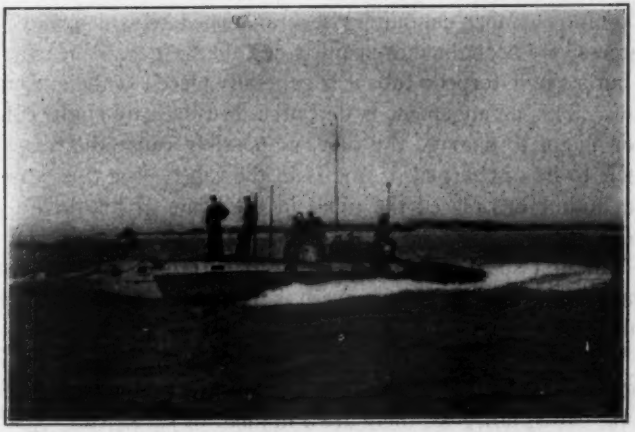
MODEL OF ITALIAN SUBMARINE, LAURENTI TYPE.

of the boat is controlled by horizontal rudders, generally arranged in pairs on both sides of the hull and connected to the same shaft. In the earlier boats only one pair of rudders was used at the bow or at the stern, but in modern practice two pairs are employed, one pair at each extreme end. In some cases the stern rudders are held at a fixed angle, and the steering effected only by those at the bow, but in other designs both sets of rudders are connected, so that they are operated together.

The behavior of a boat beneath the water is affected by a number of elements, including the metacentric height, the size and position of the horizontal rudders, the form of the hull, and the positions of the total resultants of the propelling and resisting forces. At the present time it cannot be asserted that any particular form of hull is best adapted for submarine navigation. The investigations of Taylor in the Government testing tank at Washington have not as yet given positive results, and when we consider that after many centuries of surface navigation new forms of hulls are developed, improving on the preceding ones, we may also expect a continual development in the form of submarines.

The real purpose for which a submarine is designed is the delivery of torpedoes against the enemy, and while the greatest care should be given to this feature, it is often overlooked by the designer. At the present time there is a difference of opinion as to whether it is better to have a number of external tubes from which torpedoes may be released at the proper moment, or whether internal tubes are to be preferred, from which the torpedoes may be discharged with an initial impulse in a determinate direction. In the case of the external launching tubes or cages, either rigid or swivelling, such as the Drzewiecki, the torpedo leaves the tube by the action of its own propeller, and for this reason its initial velocity is very low, and hence it is not well controlled by its rudder, so that the number of hits with this system is small. It is also found that torpedoes carried in cages outside of the hull of the submarine

are apt to become injured and are often found in bad condition. In the case of the internal torpedo tube the torpedo itself is protected, and being given a powerful initial impulse by compressed air, it starts off in the intended direction, even if its own propeller has not yet begun to act. Experience has shown that it is much easier to hit a mark with the internal tube than



EARLY TYPE SUBMARINE, "HOLLAND NO. 3."

by the use of the external cage. The objection has been urged against the internal tube, that it is impracticable to carry as large a number of torpedoes on board of a submarine as in the external cages, and that it is not practicable to discharge a torpedo at right angles to the hull, because of the insufficient width of the boat to carry cross-tubes. From a military viewpoint, however, it is better to have a few torpedoes accurately discharged than to carry a number in unreliable cages. So far as attack at right angles is concerned, this can be effected by the use of the Aubry system, in which the torpedo itself turns in its path. In the use of this system, with the Italian submersibles of the author's design, much success has been attained for several years, the torpedoes making an accurate turn of 90 degrees from the direction of discharge, in a curve of about forty meters radius, as shown in the illustration.

In the small French submarines the rigid cage, fixed in the direction of the keel, is used, while in the larger boats the swivelling cage, on the Drzewiecki system, has been adopted. In all other navies the system of internal torpedo tubes is employed. In order to enable a single tube to discharge several torpedoes, the Electric Boat Company, builders of the Holland submarine boat, have designed a form of revolver, there being a rotary chamber containing several torpedoes which may be successively brought into position and discharged. When there is but a single torpedo tube it is generally placed at the extreme bow. This arrangement is defective, because any slight collision is apt to damage the tube, or possibly cause the torpedo itself to be discharged, if one is in the tube. For this reason the author has placed the tubes in the boats of his design at some distance from the prow.

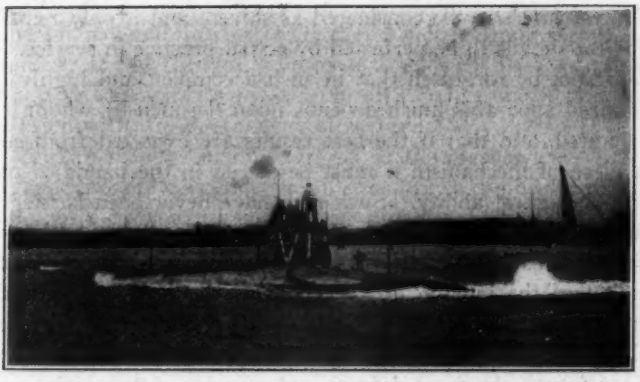
The first submarines were blind, and it was not until 1902 that satisfactory appliances were perfected for vision when submerged.

The earlier navigation was conducted by rising to the surface at frequent intervals to make observations as to direction. Now, however, there are a number of satisfactory visual appliances, among which may be mentioned the Ipoidroscope of Howard Grubb, the Telops of Triluzzi, and the Russo-Laurenti Cleptoscope. Each of these devices has its own special features. The Cleptoscope has the advantage that it may use an ocular of 20 centimeters in diameter, and with such a large lens it is possible to cover a field of nearly 50 degrees, objects being seen of natural size, using both eyes without fatiguing the vision and permitting the navigation to be conducted as effectively as with any other type of vessel. Attempts at direct vision through the water have been abandoned, since it has been found impossible, even with optical instruments, to see further than 10 to 12 meters in clear water. This is probably due to defects in human vision, which seems to be different from that of aquatic animals.

Although the commander of a submarine sees what is above his vessel he cannot see beneath it, and hence it is important

that he should be familiar with the nature of the bottom. It is impossible, however, for him to perceive the movements of another submarine in his vicinity, and hence it would be imprudent to send several submarines into the same waters without limiting closely the zone of movement of each boat. The success of recent experiments in the transmission of sound under water has led it to be considered as a method of signalling between two submarines.

The smallest diameter of a good periscope, or rather that portion of it which projects above the surface of the water, is about 10 centimeters, and this is hardly perceptible from a neighboring vessel, and its motion cannot be seen until the speed of the boat reaches about 6 knots, above which speed, as we have seen, the ripples might indicate the position of the submarine.



BRITISH SUBMARINE "A-VI," NAVIGATING AT THE SURFACE.

It is generally assumed that the air contained in a submarine is capable of sustaining life for but a very short time, and many inventors have endeavored to devise systems for the regeneration of the air. Such systems have not proved successful in practice.

It is understood that the amount of carbon anhydride in breathable air should not exceed 1.5 per thousand, while the

normal proportion is 0.4 per thousand. This means that for each person there is required nearly 20 cubic meters of fresh air per hour. This is too great a demand for the capacity of a submarine, but in practice such a quantity is not found to be necessary. It is found that strong and healthy individuals experience little inconvenience in air containing as high as fifteen parts of carbon anhydride per thousand, and that when this limit is reached it may be partially renewed by the admission of a small amount of fresh air from storage compression tanks, with the removal of a corresponding portion of the foul air, this latter being pumped from the lower part of the boat. The possibilities of surviving in contaminated air are shown in the case of the *Farfadet,* where six men lived for 36 hours in a space of only a few cubic meters' volume contaminated by acid vapors from the accumulators.

The mechanical problems involved in submarine navigation for warfare may be considered as solved, and it only remains for the details to be perfected by actual practice in service. It must not be forgotten that in such a complex and highly organized apparatus much depends upon the men by whom it is operated, and that if the best results are expected from such a piece of mechanism it must be placed in the hands of men of the highest ability. Such men have never been lacking in any civilized nation, and unforunate accidents have disclosed true heroes in the service of the submarine. Thus, by the union of the intelligence of the men who have designed the mechanism and the skill of the men by whom it is operated, the world is in the possession of an apparatus to which, in the near future, the coast defense and security of any nation may well be confided.

MELMS-PFENNINGER STEAM TURBINES.

By Ingenieur W. Muller.

Translation from "Die Turbine," by Ernest N. Janson, Member.

Translator's Notes.—The following description of the Melms-Pfenninger steam turbine, although incomplete and for the stationary type, will approximately, it is believed, answer in general features to the turbines which were ordered recently for four out of twelve German torpedo-boat destroyers, and therefore possesses interest as a marine and naval proposition. These four ships are being built by Schichau of Elbing and Danzig, who are also building turbines of same type for a small cruiser. Of the other destroyers four are building at the Germania yards at Kiel, with Parsons; three at the Vulcan yards near Stettin, with Curtis, while one will be fitted with the Zoelly type of turbines.

Practice in new turbine designs, at the present time, seems to favor moderate velocity impulse action in the high-pressure zone with low velocity impulse or combined action and reaction in the low-pressure zones. The turbine in question has foregoing features incorporated.

The mode of balancing the rotor in this turbine undoubtedly possesses merit when used in stationary practice, as the heavy and large-diameter balance pistons are partly dispensed with. The merit of the design appears to exist in the utilization of impulse action in the high-pressure zone, whereby a reduction in the number of vanes rows is rendered possible.

The steam turbine has in later years entered with a firm foothold also in Germany, especially since the inventions and system made and introduced by Parsons were brought into more practical use.

With the names of Parsons, De Laval, Rateau, Zoelly, Schultz, Reidler-Stumpf, Curtis, Westinghouse-Parsons, etc., are identified individual systems of turbine construction, which differ from the reciprocating engine, as well as between themselves, essentially in as follows: In the steam action, reliability of operation, efficiency, space allotment and durability,* any one of which characteristics appear more or less pronounced in the different types.

Fig. 1.

The steam turbine has approximately passed through developments similar to those of the water turbine, viz: First, reaction wheels, then impulse wheels, and, last, something between the two. The Melms-Pfenninger "MP" turbines, of which there is already a large number under construction,

*The author omits mentioning the very great difference in constructional details. Take as an example a Curtis and a Westinghouse turbine of same power, both for a stationary power plant, and, as is well known, there exists no similarity whatsoever in the designs as a whole nor in the construction of parts. The matter of weight enters also as an important consideration in all of the foregoing makes.

form a link between the impulse and the reaction turbines. This is carried out in a way such that in the high-pressure zone pure impulse action is used, while in the middle and low-pressure zones the impulse reaction principle is availed of.

The general arrangement provides for horizontal shaft. The steam inlet to the guide blades in the high-pressure zone is not continuous but is distributed in sections around the circumference, and, therefore, takes place so-called "partial admission."*

The clear circumferential length between the stationary blades of the H.P. zone being very considerably reduced,

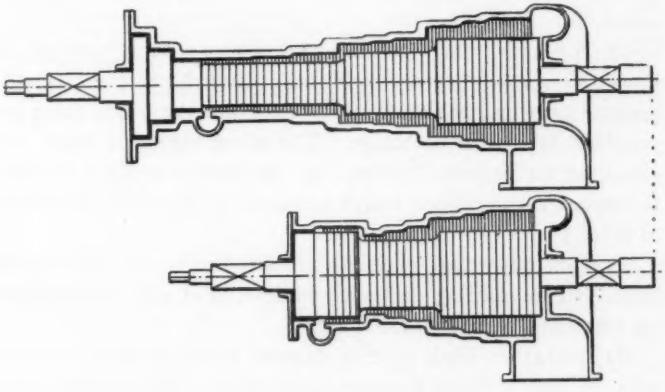


Fig. 2.

admits of longer vanes in this part of the turbine than with circumference unobstructed. The first reaction stage connects at the end of the impulse stage and the drum diameter is here made somewhat smaller. In this way a surface in form of a ring is provided to take up the unbalanced pressure existing in the vane system, which pressure causes a heavy thrust along the rotor.

This arrangement possesses, in comparison with Parsons

* In very early designs of Parsons turbines this seems to have been tried, but abandoned, owing to mechanical and dynamic reasons. This method of admitting the steam to the various pressure stages is one of the principal features of the Rateau turbine.

turbine, great simplicity, obviating its arrangement of balance pistons, and in consequence of the greater heat abstraction by using high velocities, a considerable reduction in the number of vane rows and, therefore, in the length of rotor and casing, as well as over-all diameter, is effected. Some difficulties, such as distortion of the casing caused by differences in temperature in the length direction, are disposed of and dummy clearance leakage is lessened. To illustrate the system, there are shown two views, Figs. 1 and 2. Besides the difference in length, the great difference of diameter (for same power) is apparent. In the combined reaction-impulse turbine (Parsons) it is necessary to use small diameter of drum and short vanes.*

The vanes in "MP" turbines are all on a drum and not, as in most impulse turbines, on discs. In order to diminish the leakage between the stationary vanes and the drum there are provided labyrinth packings. The advantage of a drum construction for impulse turbines is the smaller surface exposed to cause steam friction, which becomes greater with a number of discs.†

Another advantage claimed for this turbine is that superheated steam may be used without detriment, and that thereby its efficiency is considerably raised.

Superheat as high as 120 degrees Fahrenheit at the inlet may be used without danger of distortion. High vacua are, as in other turbines, used to great advantage.

The table appended gives the results of trial undertaken by Prof. Schroter of the Institute of Technology of Munchen with a turbine built for 1,000 H.P. The turbine was con-

*This depends very largely upon circumstances, such as revolutions and horsepower. Thus, with large horsepower and high revolutions, giving satisfactory vane speeds on small drum diameters, the vanes become long, giving small clearance losses. With slow revolutions and small horsepower, they, of course, become very short, with extreme clearance losses.

†The leakage owing to vane clearance must *not* be lost sight of. When on a drum this leakage becomes much larger than when discs are arranged, as then the amount of leakage is determined by the radial clearance in the bushing around the spindle shaft, while, when the drum construction is used, it is caused by an area made up from drum-circumference and radial clearance. Owing to the much higher velocity produced by the higher ratio of expansion prevalent in the individual stages of an impulse turbine, the loss from leakage would be greater than in Parsons turbine with its usually very low steam velocities, unless compensated by the labyrinth packings.

nected to two equal direct-current generators, 2,400 r.p.m. and 230 volts. The electric-driven air and circulating pumps were located in the bedplate. The steam consumption was measured by weighing the condensed steam, and observations were taken hourly under similar conditions of load.

TABLE OF TEST AND PERFORMANCE.*

Trial No.	I.	II.	III.	IV.
1. Load, kw	500.0	400.0	280.0	150.0
2. Mean revolutions per minute	2,459.0	2,469.0	2,477.0	2,489.0
3. Absolute pressure at inlet, pounds per square inch	190.2	188.8	191.7	181.7
4. Steam temperature, in degrees Fahrenheit	607.8	591.0	589.0	552.3
5. Absolute pressure in exhaust nozzle, pounds per square inch	0.5	0.37	0.378	0.52
6. Output at switchboard, kw	498.7	402.9	277.5	146.6
7. Condensation per hour, pounds water	8,570 0	8,570.0	5,140.0	3,297.0
8. Steam consumption 1 kw., pounds per hour	17 7	17 5	18.51	22.49
9. Steam consumption 1 H.P., kw.=1.34 H.P	12.81	13.06	13.8	16.78
10. Comparative steam consumption per kw. hour	100.0	101.8	107.8	130.8

*Converted into English units from the metric system.

THE ELECTRICAL EQUIPMENT OF THE CUNARD EXPRESS STEAMER *MAURETANIA*.*

By Mr. W. C. Martin.

In the equipment of a modern steamship great improvements have been made in recent years for the economical working of the vessel and for the comfort of the passengers. Of all the changes that have been made, none have been more welcome and so thoroughly appreciated as the introduction of electric light.

The first vessel to be fitted was the American steamer *Columbia*, the lighting of which was carried out under the direction of Mr. Edison in 1880. There were 115 lamps of 10 candlepower and two dynamos driven by belts from a counter shaft.

In December, 1881, Professor Andrew Jamieson delivered a lecture to this Institution, in which he stated that electric lighting was fast replacing oil lamps on steamships, and gave a description of the installation fitted on the Cunard steamer *Servia* at a cost of £1,000. When I mention that the total cost of the electrical installation on each of the latest Cunarders has been about £65,000, some idea will be formed of the great progress electrical engineering has made within the last 26 years.

Since the introduction of electricity on board ship, it has proved itself to be the "acme" of perfection for lighting, and has not only added greatly to the comfort of passengers, but has enabled shipowners to utilize lower deck spaces to better advantage for passenger accommodation; and not only passenger vessels have benefited by the adaptability, safety and economy of electricity, but the ordinary cargo steamer of the

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* Transactions of the Institution of Naval Engineers and Shipbuilders in Scotland.

present day is taking full advantage of it for the safe and rapid handling of cargo. No first-class cargo steamer is now complete without electric light, and shipowners are finding a great many charters cannot be secured unless their vessels are lighted electrically.

While it would be interesting to follow the development of the various systems of electrical installations on shipboard since the introduction of the first six kilowatt machines on the little steamer *Columbia,* to the 1,650 kilowatts in four machines on the *Mauretania,* I can only make a brief reference to some of the more important points.

In the earlier designs of dynamo construction the generators were run at a very high speed, and in many vessels the power of the engine was transmitted by belts or ropes and counter shafts to the dynamos. Belts on board ship are most objectionable, not only on account of the great space required, but because of their unsteadiness. Many attempts were made in the early days to produce some means of connecting the slow-speed engine and high-speed dynamo without belts, but even the most successful arrangement devised, namely, friction wheels, was found unsuitable for all but the smallest powers. Nothing really reliable for ship work was in use, until the advent of the high-speed steam engine made it possible to couple engine and dynamo directly together. In fact, it was this very demand for a suitable engine that led to the development and perfection of the high-speed engine and steam turbine.

The choice of an engine for electric power on board ship is about equally divided between the slow-speed type at from 200 to 300 revolutions, and the high-speed of from 500 to 700 revolutions per minute, while an occasional engineer prefers a turbine. Engineers in charge of these plants claim to have the most satisfactory results regarding efficiency and economy; but, undoubtedly, the steam turbine is the ideal for ship work. It has all the advantages of light weight, less space, steadier driving, higher efficiency under certain conditions, freedom from vibration, and, having no reciprocating parts, there is less wear. It has been proved that, in smaller

sizes, the turbines are not so economical in steam consumption, but it is almost certain that this will be overcome, and in the near future the turbo-driven dynamo will become universal.

Since the first installations many new fittings and devices have been invented for safe, reliable working on board ship, and the most important of these is the system of wiring, and the protection of the same. The first insulated wires used for ship lighting were covered with cotton cloth and white lead, and a further protection of rubber tubing when passing through specially damp places.

One of the greatest difficulties in ship lighting has been to find wires and fittings that would not be affected by sea air and water, and it still remains a fact that, no matter how good the quality of the insulating material and armored protection may be, if the wires have not been well laid by experienced men, deterioration sets in quickly with most disastrous results. Any electric installation fitted today with the best material and workmanship should last as long as the hull of the ship. Shipbuilders dare not ignore certain standard rules in the building of a ship, but in some instances they are not so particular with regard to the lighting of the same, and it would be to the interest of all concerned if insurance registries and the Board of Trade took a more intelligent interest in this kind of work.

In preparing an installation to be fitted on board ship particular attention should be paid to the placing of the wires, so that they might always be accessible and, above all things, they should be proof against fire and water.

In the Cunard steamer *Servia* there were 117 Swan lamps and 2 arc lamps equal to about 10 kilowatts of 13.4 H.P. In the *Mauretania* the total output of the four electric generators is about 2,200 E.H.P., while the actual power required for all the lights and motors running at one time is 2,773 H.P. It is found in general practice that, the power being very intermittent, two generators are capable of doing the work, thus leaving a large margin in hand for emergencies.

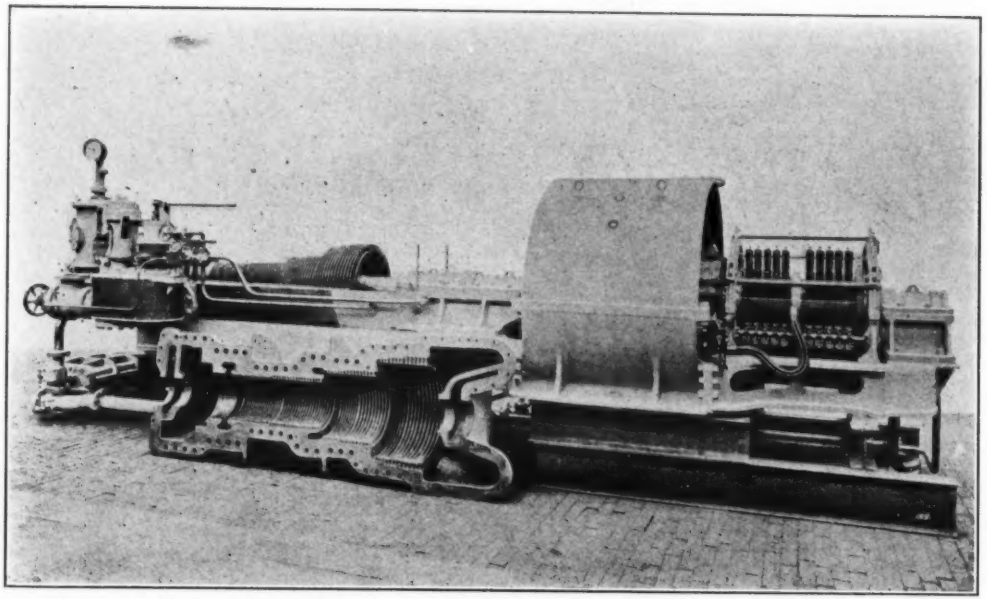


Fig. 1.

To find space for such powerful plant and to fit the installation on the safest and most reliable system, presented some interesting problems. The first of these was to determine the most suitable type of steam generator. After due consideration, the Cunard Company and the builders of the vessel decided to adopt the steam turbine, by the use of which the space required was reduced to a minimum, with less weight and more freedom from noise or vibration as compared with ordinary high-speed engines.

There are four sets of Parsons' turbo continuous-current generators, Fig. 1, each dynamo is shunt wound and is capable of giving an output of 3,750 ampères at 110 volts and 1,200 revolutions per minute. These generators are placed on an elevated platform abaft the engine room, in two separate compartments divided by a watertight bulkhead and arranged so that, in the event of either dynamo room being flooded with water, the ship could still be lighted from the unflooded side.

A better arrangement for the generators would have been to place them nearer the center of the ship, but being a vulnerable part, the Admiralty required them to be placed below the water line, hence the reason for placing them so far aft.

MAIN SWITCHBOARD.

To control this great power with safety and efficiency in a confined space exposed to a high temperature and possible trouble from vibration, required controlling-switch gear of a substantial design, yet sensitive in action. The main switchboard, Fig. 2, is divided into two parts, one section being erected in the port generating room and the other in the starboard generating room.

Each board has two generator panels, twelve feeder panels, and one disconnecting panel. Normally the two switchboards are connected together as one board through the disconnecting switches, but may be separated in a moment from *either* room, and each side of the ship operated as a separate installation.

The use of fuses for the control of the large currents dealt with would have been inconvenient and unsafe, and instead

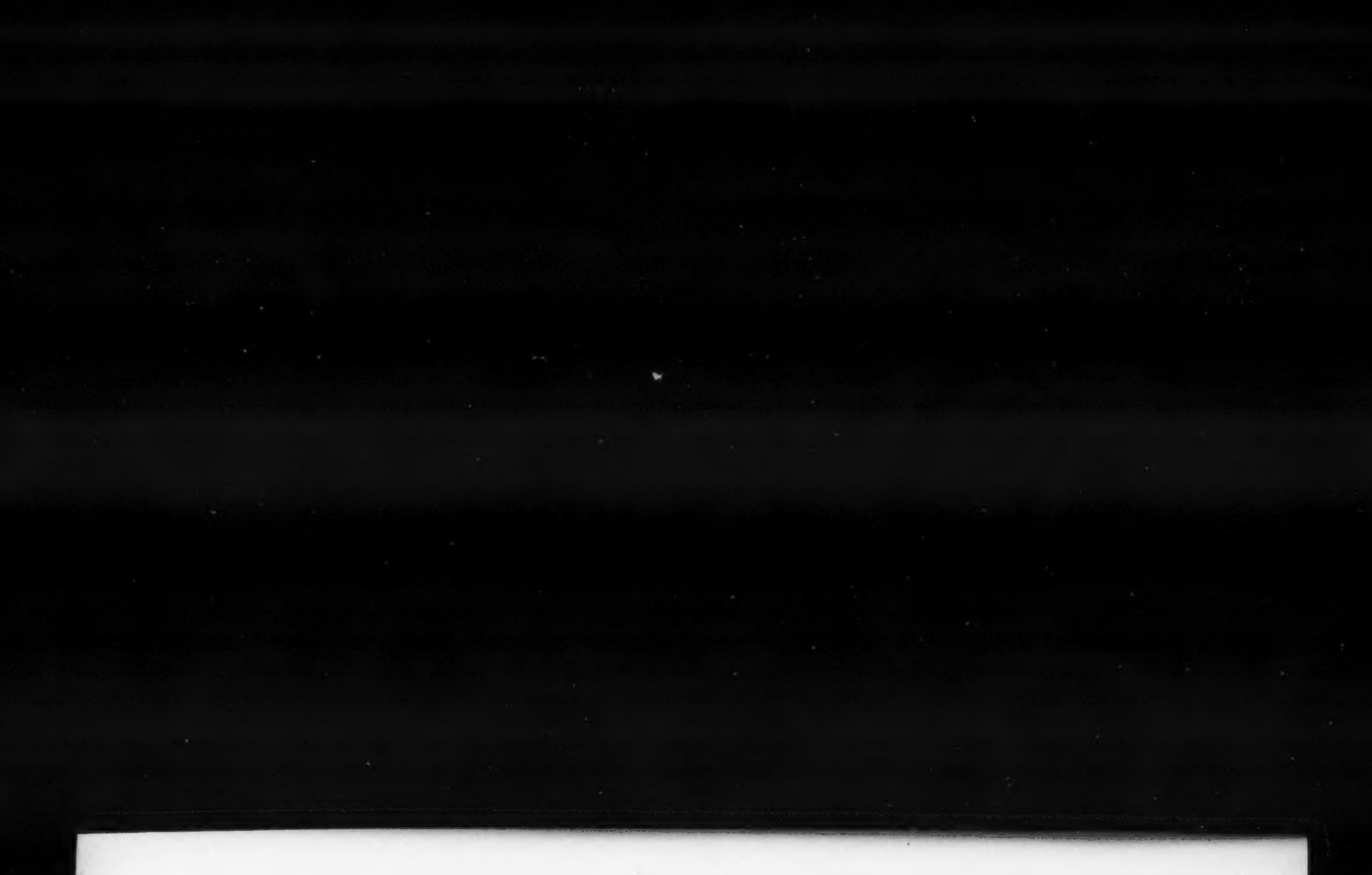
automatic circuit breakers (performing the function of both switch and fuse) were fitted.

These circuit breakers are of massive construction, the contact surfaces being pressed firmly together by levers. The make-and-break contacts are massive carbon blocks, at the extremity of the switch arms, and the main circuit breakers are so arranged that the flash at breaking takes place in fireproof compartments well clear of the attendant. To accomplish this object and to make the operation of the switches easy, the handles are placed below and connected to the switches by insulating links behind the board. These switches are held in the closed position by engaging with a trigger which may be released either by hand or by a trip coil.

In order to prevent the opening of the circuit breakers during a momentary overload, a relay is introduced which closes the trip-coil circuit when an overload occurs, after a period adjustable up to 15 seconds. Should, however, a reversal of current through the generator take place, the relay promptly closes the trip-coil circuit, and thus cuts the machine out of circuit. The opening of the circuit breaker in turn breaks the trip-coil circuit, and prevents damage to the coil or waste of energy.

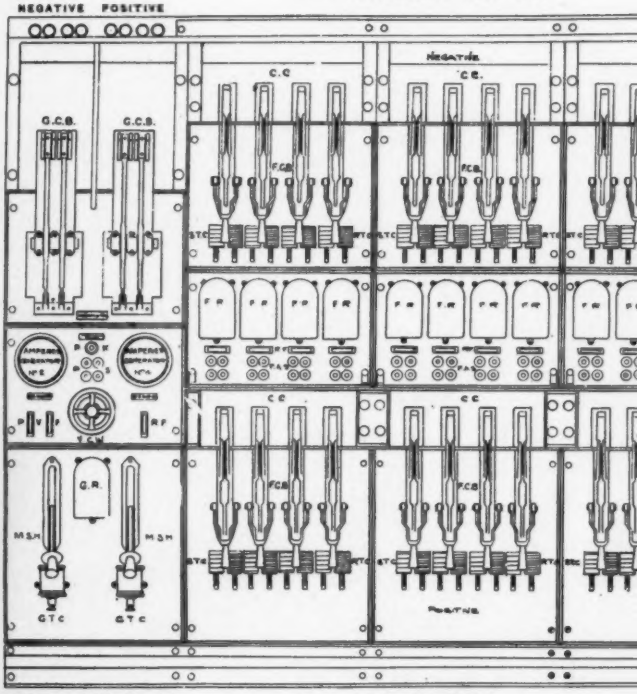
The feeder switches are operated in a similar way, but without the reverse current arrangement. They have, however, in addition, a trip coil in series with the main current, adjusted to open the circuit with a greater current than the relay is set to operate at, but instantaneous in action. Thus, should a short circuit or heavy overload occur and the relay fail to operate, damage to the cables and machinery is effectively prevented.

The relay is simple and reliable in operation. It consists of a small motor, similar to that used in meters, through which part of the current is shunted. This motor tends to wind a strong silk cord on to a drum against the pull of a weight fastened to the other end of the cord. The cord passes round a drum to which the contact arms are fitted. When the current exceeds the overload limit, the torque of the motor is



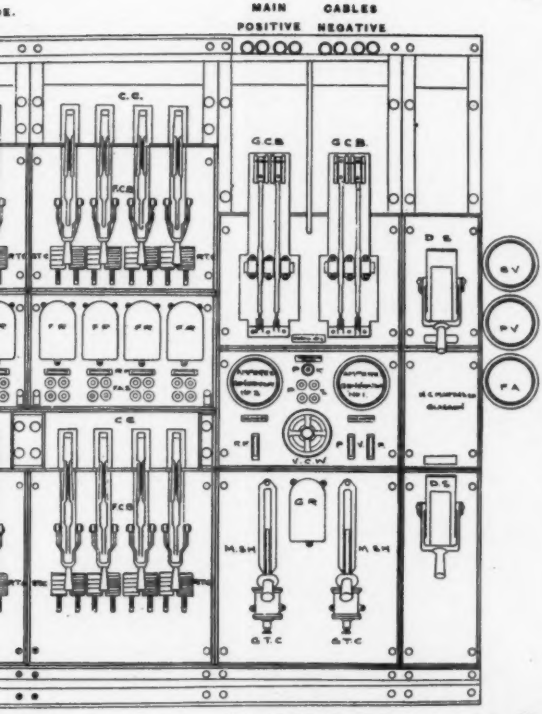
R.M.S. MAURETANIA.

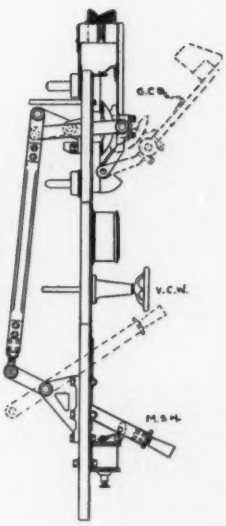
MAIN SWITCHBOARD PORT SIDE.



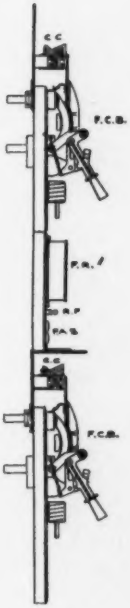
G C B	*Generator Circuit Breaker.*
P K	*Paralleling Key.*
P S	*Paralleling Socket.*
V C W	*Voltage Control Wheel.*
P V F	*Paralleling Voltmeter Fuse*
R F	*Relay Fuse.*
G R	*Generator Relay.*
M S H	*Main Switch Handles.*
G T C	*Generator Trip Coils.*
C C	*Carbon Contacts.*
F C B	*Feeder Circuit Breaker*
S T C	*Series Trip Coil.*
R T C	*Relay Trip Coil.*
F R	*Feeder Relay.*
R F	*Relay Fuse.*
F A S	*Feeder Ammeter Socket.*

Fig. 2.





END VIEW
OF GENERATOR PANEL.



END VIEW
OF FEEDER PANEL.

G C B	*Generator Circuit Breaker.*	D S	*Disconnecting Switch.*
P K	*Paralleling Key.*	B V	*Busbar Voltmeter.*
P S	*Paralleling Socket.*	P V	*Paralleling Voltmeter.*
V C W	*Voltage Control Wheel.*	F A	*Feeder Ammeter.*
P V F	*Paralleling Voltmeter Fuse.*		
R F	*Relay Fuse.*		
G R	*Generator Relay.*		
M S H	*Main Switch Handles.*		
G T C	*Generator Trip Coils.*		

THE CUNARD EXPRESS STEAMER "MAURETANIA." BY MR. W. C. MARTIN.

sufficient to wind up the cord, and thus close the trip-coil circuits. The adjustments are affected by altering the weights and varying the distance between the contacts.

All the ammeters and voltmeters are of the moving-coil type, the former being operated from shunts in the main circuits. By this means it is possible to have the reading instruments in any convenient place, and in the *Mauretania* two instruments are fitted for each machine, one being in the port and one in the starboard room. On each board one additional ammeter is fitted, connected to bars behind the feeder panels, and so arranged that it may be connected by a plug to any one circuit at a time. By this means the current in any feeder may be ascertained without the expense of separate instruments for each circuit. Two station voltmeters and two paralleling voltmeters are provided, and the shunt regulators, which are placed behind the boards, are operated by a hand wheel on the front.

MAIN CABLES.

The Cunard Company, with their usual precautions for the comfort and safety of their passengers, decided that a high voltage would not be advisable, which accounts for the current being generated at only 110 volts. This necessitated cables of a great carrying capacity, and also very heavy switch gear.

The Admiralty further required all main cables to be run under the water line, and to accomplish this it was necessary to utilize the only available spaces in the coal bunkers or through the boiler rooms. Those who have had experience in the lighting of ships will know that these spaces generally are most objectionable for electric wires, especially the coal bunkers. The high temperature of the boiler room and the very large cables necessitated special precautions being taken to prevent the heat softening the insulation and allowing the cable to sink through the rubber, causing a short circuit. With ordinary armored and lead-sheathed cables, the heat would readily affect the insulating materials. It was, therefore, nec-

essary to adopt fire-resisting covering as well as the usual vulcanized rubber, so that in addition there is a heat-resisting compound and an outer covering of two coats of asbestos braid fitted on the cables. Fig. 3 shows the method of fixing and protection of cables.

The double-wire system is used throughout, and there are 48 main cables of about 2 inches external diameter running from the generating station to the various sections of the ship, Figs. 4 and 5. The power is divided into 24 sub-stations of approximately 100 H.P. each, 12 of these being on the port side of the ship and 12 on the starboard side. Eight of these stations provide power for forced-draft fans, 2 to supply the engine-room machinery and 2 for engine-room lighting, the remaining 12 being connected to auxiliary switchboards at convenient distributing centers throughout the ship.

AUXILIARY SWITCHBOARDS.

These 12 auxiliary switchboards are placed directly opposite each other, port and starboard, and cross-connecting cables are fitted so that, in the event of one section failing, the supply can be maintained from the other side. It should be mentioned here that, as the motors are only used intermittently, there is always sufficient surplus carrying capacity in the cables to provide for emergencies of this nature, thus guarding against any total extinction of the light.

The auxiliary switchboards are fitted in fireproof chambers, principally on the main deck. The switches are single pole, and the fuses double pole—Mr. Lackie's patent zinc fuse—which breaks circuit with a minimum flash. Each board is provided with a spare panel containing spare fuses ready at a moment's notice.

BRANCH CABLES AND WIRES.

From these auxiliary switchboards vulcanized rubber cables are carried in wood casings to section fuse boxes, which again provide distributing boxes at convenient positions for supplying the lights, the wires being run without joints. It will be

noticed from Figs. 4 and 5 that these cables running from the main deck to the different sections above are like the trunk of a tree, with branches spreading out to the different decks. Special precautions were taken to keep all positive and negative wires in separate grooves.

In the corridors the casings are arranged as shown in Fig. 6, so that all wires are accessible at all times. In all the rooms of the ship the frieze forms a covering to the electric casings. A special feature of this is to be seen in the lounge, library and smoking room, and all over the ship the wires are accessible, Figs. 7 and 8. No fuse boxes have been fitted, but all fuse panels are built in specially-arranged recesses in the panelling, the panel itself forming the door; a door is also fitted behind for access to the wires. Inside the door a tablet or card is fitted, giving information of what each branch supplies, with size of fuse.

In the wiring of engine and boiler spaces and other parts of the ship exposed to rough work, the protection of the branch wires calls for special treatment. Some engineers think screwed-iron conduit or galvanized-iron tubes are most suitable, but experience has proved that tubes sweat and retain condensed moisture which very soon destroys the best insulation. The best results are obtained with parallel twin conductors, each conductor being separately insulated with pure rubber and vulcanized rubber, braided and bound together, then sheathed with an outer armor of galvanized-iron wire.

This system of armored twin conductors has special advantages for engine rooms and other exposed parts. It is compact, requires less space, and has as strong a mechanical protection as an iron tube, but does not harbor moisture about the insulation as in the case of tubes. When well coated with paint the armoring is further protected from corrosion. It is watertight and fireproof, has no soldered joints, and is always accessible.

In addition to the lighting and power circuits, there are single-core and multiple-core cables for electric bells, telephones, fire alarms, electric clocks, and the Stone Lloyd sys-

tem of indicating the position of watertight doors. These cables are too numerous to give in detail. There are over 200 miles of wire fitted, the copper in which weighs over 100 tons.

ELECTRIC LIGHTING.

There are over 6,300 lamps distributed over the ship, fitted to pendants, electroliers and brackets of various designs to suit the furnishings of the respective rooms. In the public rooms and state rooms the fittings are of a most handsome design, and the arrangement of concealed lamps for lighting the dining-saloon dome gives a beautiful sunlight effect, while other compartments are brilliantly illuminated with beautiful crystal fittings. A special feature throughout has been to design the fittings so as to obtain reflected lighting from the ceilings as well as from the lamp itself.

ELECTRIC POWER.

Electrical transmission of power was evidently not thought of when the Cunard Company built the *Servia,* and it will be interesting to follow the latest development in this branch. In every department of engineering the electrical transmission of power has become almost universal, but on shipboard it has made but little progress. In the latest Cunard steamers, however, there has been a decided advancement. In no other steamship, including the most recent German vessels, can be found anything to compare with the electric installation on the *Mauretania.*

The Cunard Company and their engineers realized that if steam were used for auxiliary work the loss through condensation in the enormous lengths of steam pipes would be very great, and also that the annoyance to passengers would be unbearable. They therefore took full advantage of the simple and more economical method of distributing the power electrically throughout the ship.

In this installation there are:—

16 motors aggregating 800 H.P. for forced draft.
28 motors aggregating 276 H.P. for ventilation of machinery space.
18 motors aggregating 400 H.P. for auxiliary machinery in engine room.
16 motors aggregating 52 H.P. for ventilating the ship.
53 motors aggregating 156 H.P. for the thermotanks supplying heated air.
4 motors aggregating 64 H.P. for refrigerating machinery.
2 motors aggregating 16 H.P. for two passenger elevators.
4 motors aggregating 108 H.P. for lifeboat winches.
8 motors aggregating 48 H.P. for electric jib cranes.
6 motors aggregating 78 H.P. for mails and baggage hoists.
6 motors aggregating 20 H.P. for hoists and stores.
2 motors aggregating 10 H.P. for printing machinery.
1 motor aggregating 5 H.P. for wireless telegraphy.
20 H.P. for pantry and kitchen service machinery and hot plates.
80 H.P. for 106 electric radiators for special state rooms, bath rooms and hospitals.

A total of 2,133 H.P. independent of the power for lighting.

The forced draft for the main boilers is supplied by 32 fans arranged in pairs and driven by 16 electric motors of 50 H.P. each; the motors are of the enclosed type, developing the power at 450 revolutions per minute, with the current at 110 volts. The fan impellers are of the single inlet type, being 66 inches in diameter and each capable of delivering 33,000 cubic feet of air per minute, against a water pressure of 3¼ inches on the discharge side when running at 450 revolutions per minute.

Owing to the high temperature in which these motors have to work, a very ingenious arrangement is provided whereby they may be cooled. Situated between the motor at the commutator end and one of the 66-inch fans, is an auxiliary fan with separate casing, the disc being 48 inches in diameter and made of sheet brass. The discharge is connected to the under

side of the motor and plate, the air being circulated round the commutator and armature, and leaving at the opposite end. Each fan is provided with a water gauge and tachometer. Fig. 9 illustrates a forced-draft motor and fan. Each motor is also fitted with a controller or switch capable of regulating the speed in equal increments by field variation from 225 to 450 revolutions per minute. Low voltage and overload automatic releases are fitted to these controllers, giving complete protection to the motors under all conditions.

When running at the lowest speed the approximate output of air from each fan is 17,000 cubic feet per minute, against a water pressure of 1 inch. Each fan room is also ventilated by 8 single-inlet fans 21 inches in diameter, each being driven by a motor of the totally-enclosed type capable of delivering 1,000 cubic feet of air per minute against a water pressure of 1 inch, when running at a speed of 900 revolutions per minute.

The motors are of the four-pole series-wound type, and are each capable of developing normally an output of 5 H.P. when supplied with current at a pressure of 110 volts and running at a speed of 900 revolutions per minute. Each motor is supplied with a controlling panel consisting of a one double-pole quick-break switch, tubular fuses and starting and regulating resistances, the whole being self contained and mounted upon a panel suitable for erection on the bulkhead.

In the engine room the electric motor performs a most important part in the manipulation of the main turbines and other gear. For dismantling the turbines there are six sets of lifting gear, each consisting of a 30-H.P. motor, driving a horizontal shaft above the turbine, coupled to two 7-inch diameter vertical lifting screws and worm gear, by which means the turbine casing or rotor can be lifted in turn, Fig. 10. The weight of the L.P. rotor is about 125 tons and the H.P. rotor 72 tons, and these can be lifted in 30 minutes.

One of the best illustrations of the adaptability and usefulness of electric motors on board ship is to be found in the case of the electrically-controlled sluice valves. There are two 75-inch and two 60-inch sluice valves in connection with the

high-pressure turbine exhaust steam, and in each of these is fitted a 12-H.P. motor operating a worn gear, as shown in Fig. 11. Each is controlled from switches, Fig. 12, on the starting platform, where an index shows the action of the valve. The fact that the valves can be closed in a minute or two by the electric motor, and that it would take four men 2½ hours to close it by hand, shows a remarkable saving in time and labor in favor of the electric motor. Other useful applications of the electric motor in the engine room is the 30-H.P. motors installed for the turning gear, and 25-H.P. motors which drive centrifugal pumps drawing off surplus water from the condensers.

For ventilating the engine room there are ten Sirocco fans of 25 inches diameter, each driven by a 5-H.P. motor; six fans of 30 inches diameter, each driven by a 30-H.P. motor; and four fans of 15 inches diameter coupled to 1½-H.P. motors.

The general heating and ventilating of the ship is maintained by 53 thermotanks, each fitted with a motor-driven fan, the motors varying from 2½ to 4 H.P., making a total of 156 H.P., Fig. 13. Each motor fan supplies a section of the ship with warm or cold air, or, by arrangement of valves on the tanks, the fans can be made to extract the air from various compartments.

DECK WINCHES AND OTHER APPLIANCES.

Electric-power driving is also extensively used for deck winches, passenger hoists, and other appliances to the extent of 270 H.P.

For the passenger lift, two motors of 8 H.P. supply the power to the winding gear, Fig. 14, while other two motors of 15 H.P. supply the power for two 40-cwt. baggage hoists, and two 5-H.P. motors operate two 10-cwt. store hoists, while two more of 1½ H.P. control the two 2-cwt. pantry hoists for conveying food from the kitchen. There are also two mail hoists fitted with 12-H.P. motors.

In addition to these there are four electric jib cranes, each

made to lift 12 cwts., Fig. 15. The lifting motions are operated by a 12-H.P. motor through worm gear, and the slewing motion through worm and spur gearing by a 2½-H.P. motor, the motors being series wound of the enclosed type. These cranes do their work absolutely without noise of any kind, and are conveniently placed on the boat deck for lifting stores, or luggage and mails from tenders that come alongside.

Another important part performed by electric power is the hoisting and lowering of the lifeboats. This work is done by four electric winches placed alongside the lifeboats, Fig. 16. The motors attached to these winches are each of 27 H.P. connected to worm gear running in an oil bath. The rapidity with which the lifeboats can be manipulated, as compared by hand, must be apparent to all.

An interesting application of electric driving is in connection with the refrigerating machinery, Fig. 17.

The two gas compressors are each coupled direct to a 12-pole shunt-wound motor of 35 H.P., giving a constant torque between 40 and 110 revolutions per minute. The armature is provided with two windings which are in series at starting, and by turning the hand-wheel on the switch-gear, the starting resistance is cut out and a variable resistance inserted in the shunt circuit to regulate the speed between 35 and 75 revolutions per minute. By transposing the armature windings from series to parallel connections without resistance, and by inserting the shunt resistance again, the speed can be increased to 110 revolutions per minute. The two brine pumps are operated by shunt-wound motors of 3½ H.P. each.

In addition to the large number of motors already enumerated, there are still a great number of other applications, but time will only permit me to refer to them briefly.

Among these are the motors for driving the printing machine and the Marconi apparatus of 5 and 3 H.P., respectively, and provision is made by having connections on deck for driving winches of 112 H.P. on the quay or in barges. In the galleys and cooking department an electric motor drives a machine capable of making bread for 3,000 people; and in the

cooking ovens there are four vertical spits, driven electrically, capable of dealing with a half-ton of meat at a time; other motors are fitted to knife-cleaning machines, dish-washing machines, circular knives for cutting bacon, potato peelers, whisking machine, freezing machines for making ice cream, and numerous electric hot plates for keeping food warm during service.

TELEPHONE AND ELECTRIC BELL SYSTEM.

Telephone instruments are fitted throughout the first-class state rooms. Having an exchange on board, passengers can converse with one another without leaving their rooms. On arrival in port the exchange is connected to the Liverpool or New York exchange, so that passengers may be in communication with their homes or offices up till the hour of sailing or immediately on arrival.

Another telephone system connects the captain and officers on watch on the bridge with the engine rooms, and crow's nest on the foremast. These consist of Graham's navy-pattern loud-speaking telephones, and are used for docking and steering as well, connections being fitted on the forecastle, in the wheel house aft, and in the steering-gear room at the stern of the ship. For the officers' use there is an intercommunication telephone service fitted, consisting of the Parsons Sloper secret instruments, each officer being able to call up another from his own room.

In addition to the telephone system there is a large installation of electric bells with Gents' patent indicators. In every first-class state room there is a combination fitting of electric-bell push, electric-light switch, connection for portable reading lamp or curling-tongs heater, and electric fans, while a number of special rooms are fitted with electric radiators.

A complete installation of electric clocks is fitted on the magnetic system. In the public rooms and principal entrances and corridors there are fitted, in all, forty-eight clocks, controlled from the master clock, situated in the chart room adjoining the bridge.

There is also a complete electric fire-alarm system. A brass plate and red lamp indicate the position of the alarm push in the corridors, these being connected to indicators in the engine room and the navigating house on the bridge deck. There is also a subsidiary fire-alarm apparatus fitted near the bridge, consisting of a small cabinet into which a number of tubes are led from the various holds, a small electrically-driven fan continually exhausts the air from the tubes, and in the event of a fire it would be easily detected from which hold the smoke issued. A mercury-contact type fire-alarm indicator is also fitted in the case, which, with the rising temperature, rings an alarm bell.

In addition to the ordinary life buoys, there are two special buoys fitted on the bridge deck operated by Martin's electric release gear, which can be operated from the bridge and other positions, on the alarm being raised.

In connection with the Stone Lloyd system of watertight doors, an electric indicator is fitted in the navigating house which shows the position of every watertight door in the ship, Fig. 18. The doors are closed or opened by hydraulic power simultaneously, by the officer in charge moving a handle which operates the control valve. The function of the electric indicator is to show the officer exactly what doors are open or closed. The indicator has a small lamp for each door with wires led to a contact switch at the door which, when the door is closed, completes the lamp circuit and lights the lamp.

Another important fitting on the bridge is Martin's automatic indicator for the navigating lamps, which is shown open and closed in Fig. 19. The indicator controls five lights as shown, each light consisting of a duplicate-filament lamp, one filament being lighted normally. In the event of this filament failing, the armature of a small electro-magnet which is in circuit is released, and falls against an auxiliary contact, which completes a circuit through the remaining lamp filament and through the indicator lamp corresponding to the light affected. Attention is also drawn to the occurrence by an electric horn attached to the indicator. On the officer in

charge pulling a handle the horn ceases to sound, and the electro magnet is inserted in circuit with the second filament; should this latter fail the horn again sounds, and cannot be stopped until the lamp is replaced or switched off. The several lamp circuits are controlled by the slipper switches seen under the indicator, and the latter—as, indeed, all the important apparatus on the ship—is connected through a change-over switch from either the port or starboard feeder systems, thus guarding against a failure in the navigating lights.

In conclusion, I commend to marine engineers and naval architects a closer study of the advantages of electrical power driving for all auxiliary machinery. The question of propelling the ship by electric motors awaits development, but the electrical equipment of the *Mauretania* shows many advantages over the present wasteful system of steam engines.

DESCRIPTION AND OFFICIAL TRIALS OF THE U. S. S. *SALEM.*

By C. B. Edwards, Associate.

The *Salem* is a high-speed scout cruiser, built by the Fore River Shipbuilding Co., with hull from Navy Department's designs and propelling machinery from builders' designs.

The contract was signed May 17, 1905, and calls for a vessel having a trial displacement of 3,750 tons and to fulfill the following trial requirements:

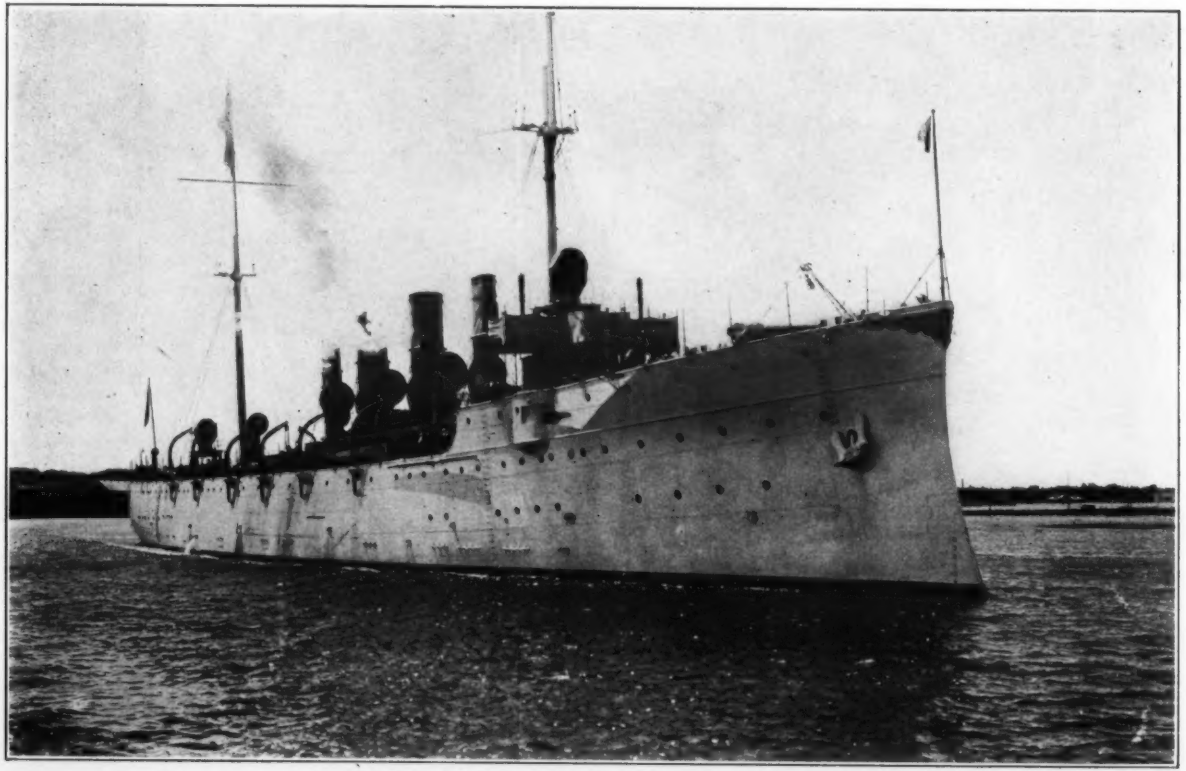
1. A full-speed trial for four hours at sea at not less than 24 knots.

2. An endurance and coal-consumption trial at sea for twenty-four hours at not less than 22½ knots.

3. An endurance and coal-consumption trial at sea for twenty-four hours at not less than 12 knots.

The speed in all the above trials was to be measured by the average revolutions of the propellers as determined by a standardization trial on a measured mile previous to the sea trials. On the 22½-knot endurance run the contract also requires that the vessel make 1.8 knots per ton of coal.

The *Salem* is one of the three sister ships contracted for at the same time, the other two being the *Birmingham*, built by the same company, and the *Chester*, built by the Bath Iron Works. The *Salem* is propelled by twin-screw Curtis marine reversible turbines, the *Birmingham* by twin-screw reciprocating engines, and the *Chester* for four-screw Parsons turbines, while the lines and other machinery of all three vessels are practically identical. This makes the trials of these three vessels especially interesting on account of giving direct comparisons of these three systems of propelling engines.



U. S. Scout Cruiser "Salem."

HULL.

The vessel carries an armament of two 5-inch and six 3-inch guns and two 21-inch submerged torpedo tubes, and has 2-inch nickel-steel protection on the sides in way of machinery spaces. The principal dimensions are as follows:

Length between perpendiculars, feet	420
over all, feet and inches	423–2
on L.W.L., feet	420
Breadth, extreme, feet and inches	47–0¾
molded, feet and inches	46–8
on L.W.L., feet and inches	46–8
Draught, trial, at 3,750 tons, feet and inches	16–8½
fully loaded, at 4,710 tons, feet and inches	19–2½
Depth molded main deck, M. S., feet and inches	36–5 1/16
Displacement per inch at L.W.L., tons	30.8
Area of midship section, trial draught, square feet	566
L.W.L. plane, trial draught, square feet	12,960
wetted surface, trial draught, square feet	19,900
Capacity of coal bunkers at 43 cubic feet per ton, tons	1,358
reserve feed-water compartments, tons	116½
Block coefficient, trial draught	.40
Midship coefficient, trial draught	.72
L.W.L. plane, trial draught	.66

MAIN ENGINES.

The propelling engines consist of two Curtis marine reversible turbines, one on each of the two shafts. The turbines have a designed aggregate of 16,000 brake horsepower at 350 r.m.p., with 250 pounds steam pressure in chest. Each turbine has a pitch diameter of the wheels of 120 inches and is of the 7-stage type, having seven ahead wheels and two reverse wheels; each wheel has three rows of moving buckets, except the first ahead wheel, which has four rows.

These turbines are identical with those of the Southern Pacific Co. steamer *Creole*, described and illustrated with drawings in the author's paper in "JOURNAL A. S. N. E.," No. 3, of Vol. XIX, except that here the areas of the nozzles are double those of the *Creole*, as the designed power is twice as much, and provision must be made for twice the volume of steam to flow.

The turbines are located in separate engine rooms, the starboard room being forward of the port, as the vessel is not wide enough to permit both being arranged athwartships. Each turbine is controlled by two operating levers which admit steam through balanced throttle valves to either the ahead or astern steam chest. The arrangement of engine room is shown in Fig. 2. Each turbine has a thrust bearing with horseshoes. The thrust shaft is 12 inches in diameter, and has twelve collars 19 inches in diameter and 1⅛ inches thick.

PROPELLERS.

The contractors made four different sets of propellers, which were all carefully tried on the measured mile and the best set selected for the official trials. The design finally used was of the 3-bladed, cast-solid, twin-screw type, of the following dimensions:

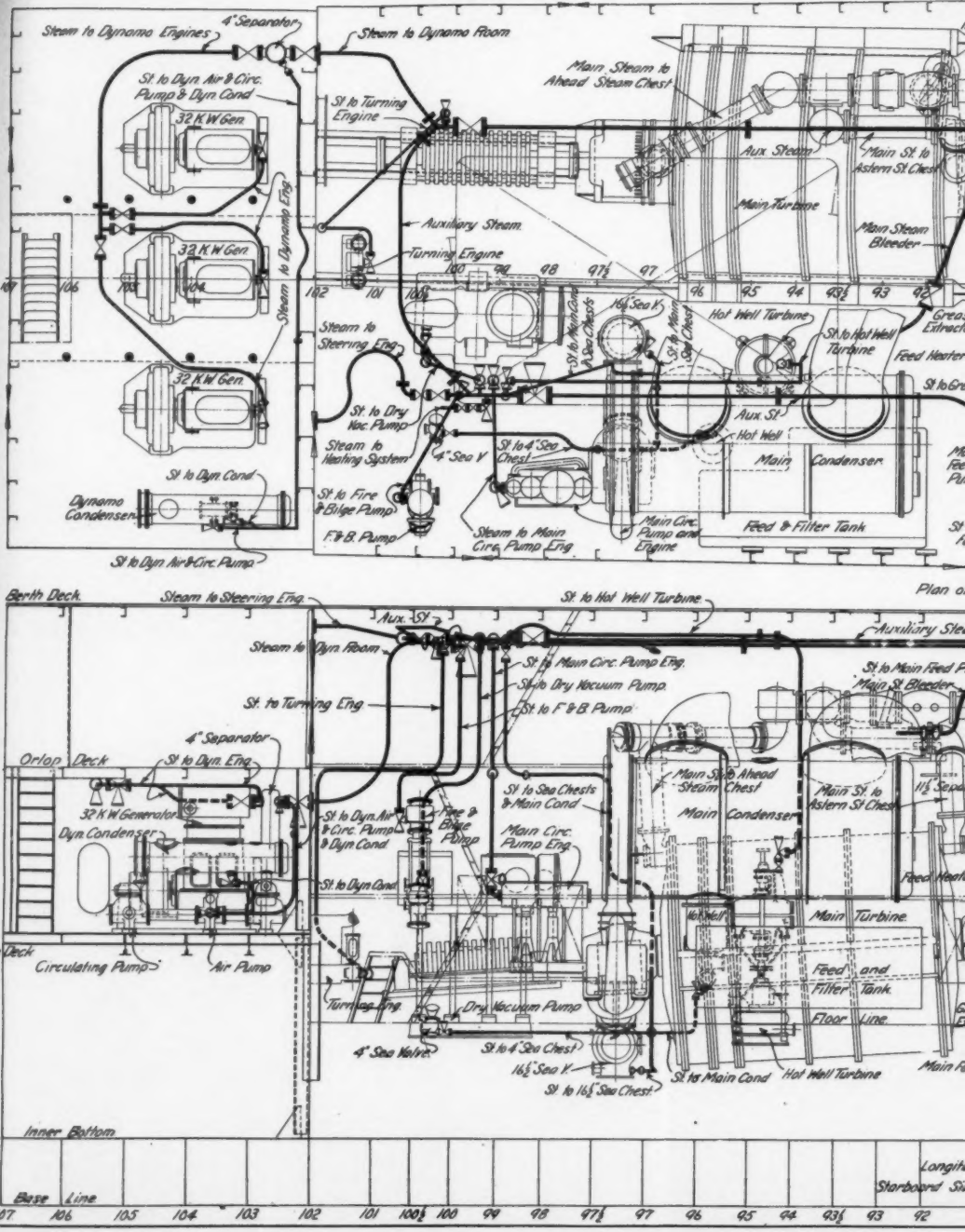
Diameter, feet and inches	9–06
Pitch, feet and inches	8–08½
Pitch, ratio	.916
Developed area, square feet	43.7
Projected area, square feet	36.8
Developed area, ratio	.617
Projected area, ratio	.52
Diameter of hub, inches	24
Immerson of upper tip at load draught, inches	80

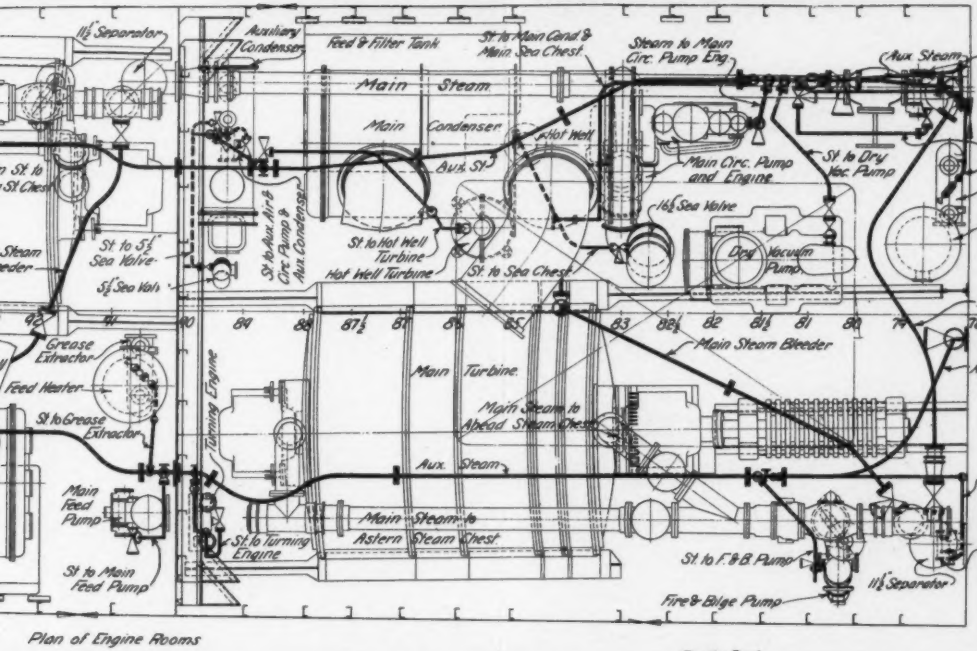
Turn outboard.

BOILERS.

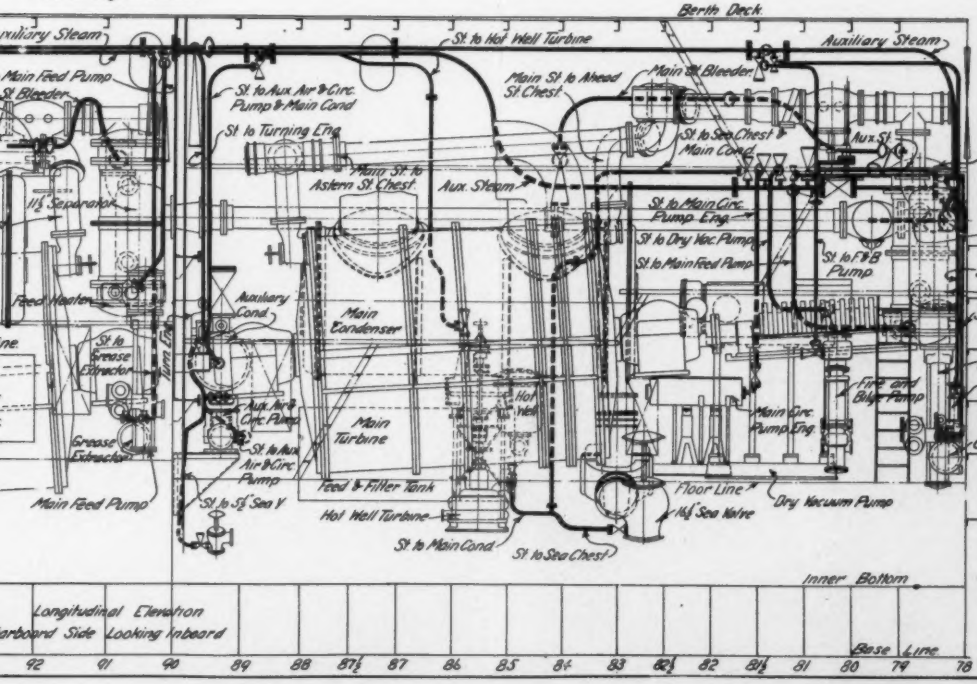
Twelve boilers of the Fore River type are installed in three separate compartments, as shown in Fig. 3. The boiler data are as follows:

Working pressure, pounds per square inch	275
Test pressure, pounds per square inch	400
Length of grate, feet and inches	7–03
Width of grate, feet and inches	8–00
Grate surface one boiler, square feet	56
Heating surface one boiler, square feet	3,166
Total grate surface, square feet	696
heating surface, square feet	37,992

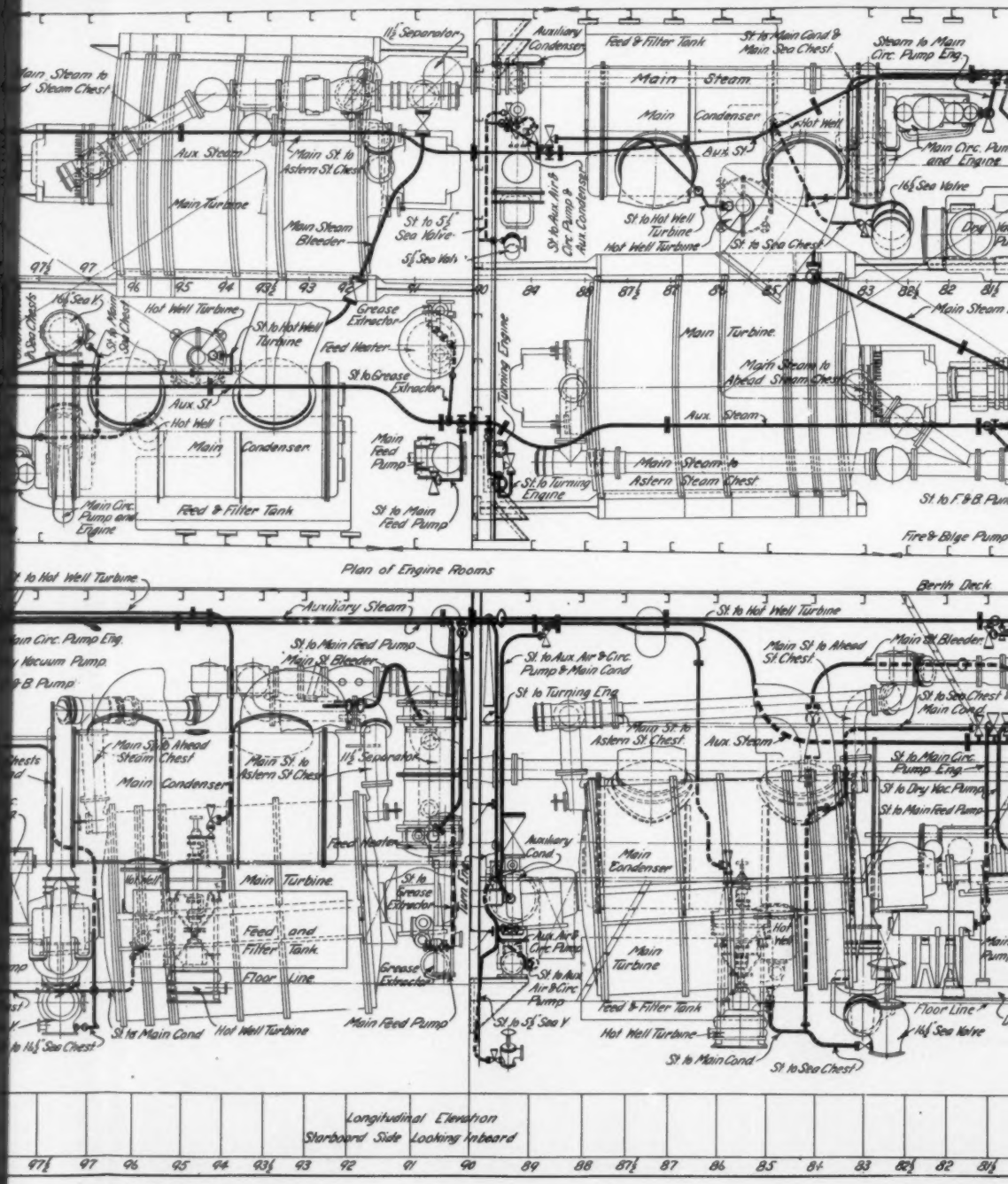

Steam to Dynamo Engines
4" Separator
Steam to Dynamo Room
St. to Dyn. Air & Circ. Pump & Dyn. Cond
32 K.W Gen.
32 K.W Gen.
32 K.W Gen.
Steam to Dynamo Engs.
St. to Turning Engine
Main Steam to Ahead Steam Chest
Aux. Steam
Main St. to Astern St. Chest
Main Turbine
Main Steam Bleeder
Auxiliary Steam
Turning Engine
Steam to Steering Eng.
St. to Dry Vac. Pump
Steam to Heating System
4" Sea V.
St. to 4" Sea Chest
St. to Fire & Bilge Pump
F. & B. Pump
Steam to Main Circ. Pump Eng.
Main Circ. Pump and Engine
Hot Well Turbine
St. to Hot Well Turbine
Feed Heater
Aux. St.
Hot Well
Main Condenser
Feed & Filter Tank
St. to Dyn. Cond.
Dynamo Condenser
St. to Dyn. Air & Circ. Pump
Berth Deck.
Steam to Steering Eng.
St. to Hot Well Turbine
Aux. St.
Steam to Dyn. Room
St. to Main Circ. Pump Eng.
St. to Dry Vacuum Pump.
St. to Turning Eng.
St. to F. & B. Pump
4" Separator
Orlop Deck.
St. to Dyn. Eng.
32 K.W Generator
Dyn. Condenser
St. to Dyn. Air & Circ. Pump & Dyn. Cond
Fire & Bilge Pump
St. to Sea Chests & Main Cond
Main Circ. Pump Eng.
Main St. to Ahead Steam Chest
Main Condenser
Main St. to Astern St. Chest
St. to Dyn. Cond.
Hot Well
Main Turbine.
Platform Deck
Circulating Pump
Air Pump
Feed and Filter Tank.
Floor Line.
Turning Eng.
Dry Vacuum Pump
4" Sea Valve
St. to 4" Sea Chest
16½" Sea V.
St. to 16½" Sea Chest
St. to Main Cond
Hot Well Turbine
Inner Bottom
Base Line
Starboard Side
107 106 105 104 103 102 101 100½ 100 99 98 97½ 97 96 95 94 93½ 93 92

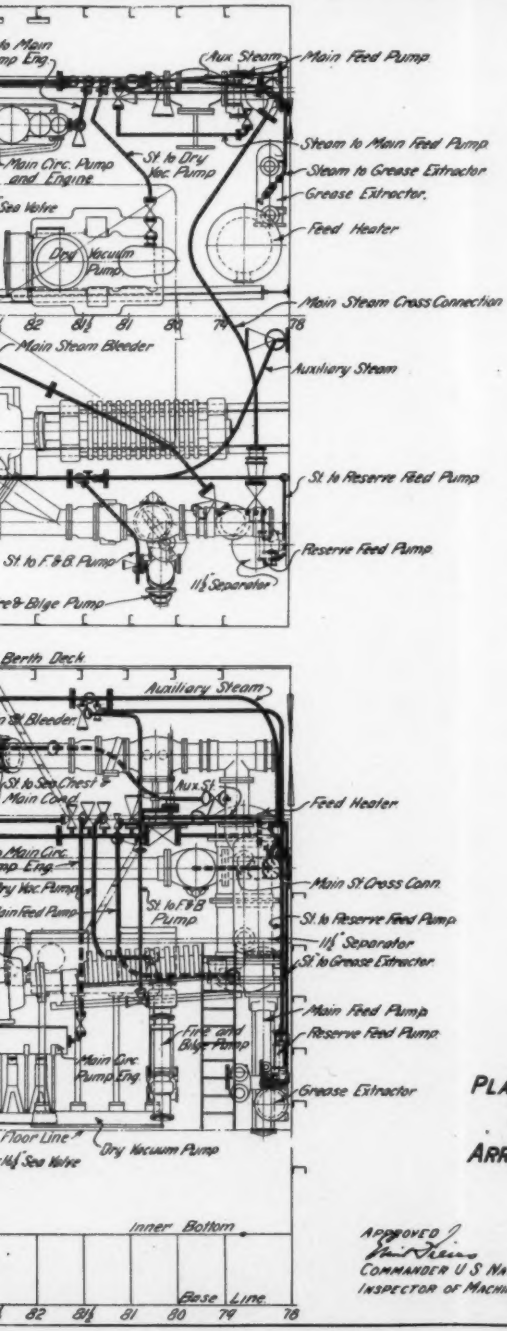


Plan of Engine Rooms


Berth Deck
Auxiliary Steam
St. to Hot Well Turbine
Main Feed Pump
Main St. Bleeder
St. to Aux. Air & Circ. Pump & Main Cond
Main St. to Ahead St. Chest
Main St. Bleeder
St. to Turning Eng.
St. to Sea Chest & Main Cond.
Aux. St.
Main St. to Astern St. Chest
Aux. Steam
St. to Main Circ. Pump Eng.
St. to Dry Vac. Pump
St. to Main Feed Pump
St. to F. & B. Pump
1½ Separator
Feed Heater
Auxiliary Cond.
Main Condenser
St. to Grease Extractor
Aux. Air & Circ. Pump
Hot Well
Main Turbine
Fire and Bilge Pump
Main Circ. Pump Eng.
Grease Extractor
St. to Aux. Air & Circ. Pump
Main Feed Pump
Feed & Filter Tank
Floor Line
Dry Vacuum Pump
St. to 5½ Sea V.
Hot Well Turbine
St. to Main Cond.
St. to Sea Chest
Inner Bottom
Base Line
92 91 90 89 88 87½ 87 86 85 84 83 82½ 82 81½ 81 80 79 78

Longitudinal Elevation
Starboard Side Looking Inboard


1½ Separator
Auxiliary Condenser
Feed & Filter Tank
St to Main Cond & Main Sea Chest
Steam to Main Circ. Pump Eng
Main Steam
Main Condenser
Hot Well
Aux. Steam
Main St to Astern St Chest
Main Turbine
Main Steam Bleeder
St to 5½ Sea Valve
St to Aux. Air & Circ. Pump & Aux Condenser
St to Hot Well Turbine
Hot Well Turbine
St to Sea Chest
16½ Sea Valve
Main Circ. Pump and Engine
Hot Well Turbine
St to Hot Well Turbine
Grease Extractor
Feed Heater
St to Grease Extractor
Aux. St
Hot Well
Main Condenser
Main Feed Pump
Main Circ. Pump and Engine
Feed & Filter Tank
St to Main Feed Pump
Turning Engine
Main Turbine
Main Steam to Ahead Steam Chest
Aux. Steam
Main Steam to Astern Steam Chest
St to Turning Engine
St to F & B Pump
Fire & Bilge Pump
Plan of Engine Rooms
St to Hot Well Turbine
Auxiliary Steam
Main Circ. Pump Eng.
Vacuum Pump
F & B Pump
St to Main Feed Pump
Main St Bleeder
Main St to Ahead Steam Chest
Main St to Astern St Chest
1½ Separator
Main Condenser
Feed Heater
Hot Well
Main Turbine
Feed and Filter Tank
Floor Line
St to Grease Extractor
Grease Extractor
St to Main Cond
Hot Well Turbine
Main Feed Pump
St to Aux. Air & Circ. Pump & Main Cond
St to Turning Eng
Main St to Astern St Chest
Aux. Steam
Auxiliary Cond
Main Condenser
Aux. Air & Circ. Pump
St to Aux. Air & Circ. Pump
St to ½ Sea V
Main Turbine
Feed & Filter Tank
Hot Well Turbine
St to Main Cond
St to Sea Chest
Berth Deck
St to Hot Well Turbine
Main St Bleeder
Main St to Ahead St Chest
St to Sea Chest
Main Cond
St to Main Circ. Pump Eng
St to Dry Vac. Pump
St to Main Feed Pump
Floor Line
16½ Sea Valve
Longitudinal Elevation
Starboard Side Looking Inboard
97½ 97 96 95 94 93½ 93 92 91 90 89 88 87½ 87 86 85 84 83 82½ 82 81½



U.S.S. SALEM.

PLAN AND LONGITUDINAL SECTION ENGINE AND DYNAMO ROOMS ARRANGEMENT OF STEAM PIPES

0 1 2 3 4 5 6

APPROVED
COMMANDER U.S. NAVY
INSPECTOR OF MACHINERY

(2)

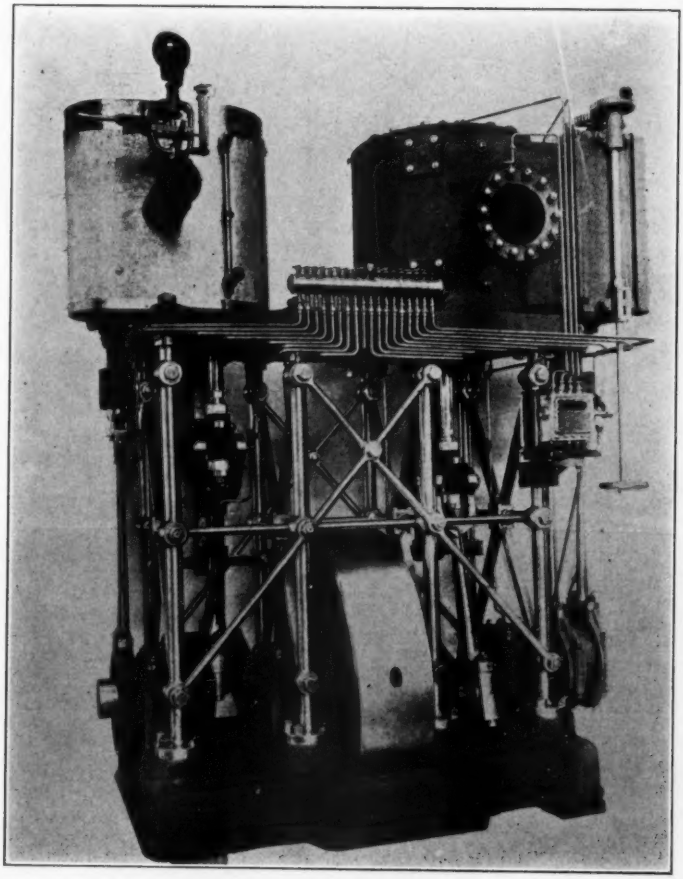


Fig. 3.—Dry Vacuum Pump.

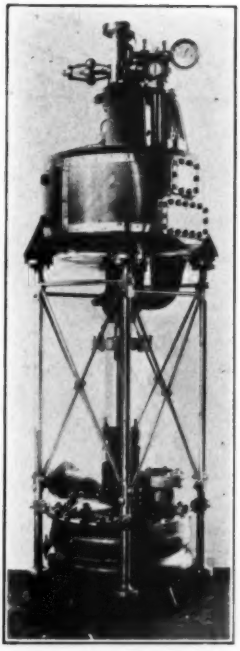


Fig. 4.—WET VACUUM CENTRIFUGAL TURBINE HOT-WELL PUMP.

Ratio	54.6
Tubes, No. 11 B. W. G., diameter outside, inches	1¼
per boiler, 34 rows of 43 each, making a total of	1,462
Area of smoke pipes handling two boilers, square feet	17.6
four boilers, square feet	34.9
Height of smoke pipes above grate, feet	63

MAIN CONDENSERS.

Each turbine has located at its side one Worthington type horizontal cylindrical surface condenser. The cooling water passes through twice, coming in through the lower and going out through the upper half of the tubes. At the bottom of each condenser is a baffle plate, which separates the condensed steam from the entrained air. The condensed steam flows to a hotwell consisting of a casting fastened to the outside of the shell and then to the suction pipe of the centrifugal wet hotwell pumps. The air flows out through a separate nozzle on the condenser shell to the dry-air pump.

Cooling surface, square feet	9,460
Number of tubes	4,448
Length of tubes, feet and inches	13–2
Outside diameter of tubes, inch	¾
Thickness of tubes	No. 16 B. W. G.
Two exhaust-steam inlets, diameter each, inches	42

DRY-AIR PUMPS.

Each turbine has one Blake rotary vertical dry-air pump (as shown in Fig. 3), having one steam cylinder and one air cylinder, each double acting. Each cylinder has a connecting rod and crank, operating on the same crank shaft, which carries a flywheel between the two cranks.

Steam cylinder, diameter, inches	10
Air cylinder, diameter, inches	24
Stroke of both, inches	18

CENTRIFUGAL HOTWELL PUMPS.

The condensed steam is drawn out of each condenser by a Worthington vertical, 2-stage, centrifugal, hotwell pump, di-

rect driven by a small Curtis turbine 27 inches in diameter, 2-stage, as shown in Fig. 4. The pump has 4-inch suction and discharge, and runs at 1,200 r.p.m. designed.

MAIN CIRCULATING PUMPS.

Each main condenser has one double-inlet centrifugal circulating pump, direct driven by a compound engine. The pumps have 16½-inch-diameter discharge nozzles, and are designed to deliver 11,000 gallons of water per minute each at 360 r.p.m.

MAIN FEED PUMPS.

In each engine room there is one Blake vertical simplex feed pump, 15×10×15, with suction from feed tanks and discharge through a grease extractor to main feed line.

AUXILIARY FEED PUMPS.

Three auxiliary feed pumps are installed, one in each fireroom. Each is a Blake vertical simplex, 9×6×12.

FORCED-LUBRICATION SYSTEM.

The main turbine bearings and thrust blocks in each engine room are provided with a separate forced-lubrication system. The oil is first delivered by a pair of 4×6×6 vertical simplex oil pumps to a 100.gallon distributing tank in the engine hatch, and from there flows to the bearings. The drain from the bearings goes to a 110-gallon settling tank on the inner bottom, which is provided with cooling coils taking cooling water from the main circulating pump.

FORCED-DRAFT FANS.

Six Sturtevant fans are installed for forced draft on the closed-fireroom system, being two to each stoke hold. Each fan is 66 inches diameter and 24 inches width at tips of blades, and is of the double-inlet type, with 42-inch-diameter intakes, and is driven by a double engine, 6×6.

FEED-WATER HEATERS.

There are two Wheeler vertical feed-water heaters, one being installed in each engine room. Each has 600 square feet of heating surface composed of 679 tubes, $\frac{5}{8}$-inch diameter, 5 feet 7 inches long and No. 16 B. W. G. These heaters are of the pressure type, with the feed water passing through the inside of the tubes and the auxiliary exhaust steam being piped to the casing and surrounding the tubes. The condensation is piped to the condenser and also to the feed tank.

FEED AND FILTER TANKS.

In each engine room, under the main condenser, there is a galvanized-iron feed and filter tank of about 1,500 gallons capacity. The filter compartment is of the usual construction and has a capacity of about 300 gallons. Loofa sponges are used for filtering.

AUXILIARY CONDENSER.

An auxiliary condenser is located in the forward engine room, having 600 square feet of cooling surface composed of 566 tubes $\frac{5}{8}$-inch diameter, 6 feet 8 inches long, and No. 16 B. W. G. It has a combined air and circulating pump $6\times10\times10\times12$.

EVAPORATING PLANT.

An evaporating and distilling plant, having a capacity of 16,000 gallons of fresh water per day, is installed. There are four Williamson evaporators, each having 223 square feet of heating surface of 2-inch brass tubes, and four distillers each having 80 square feet cooling surface of $\frac{5}{8}$-inch tinned-brass tubes. There are two distiller circulating pumps $10\times10\times2$, horizontal simplex, one evaporator feed pump $4\frac{1}{2}\times5\times6$, vertical simplex, and one fresh-water pump $4\frac{1}{2}\times5\times6$ vertical simplex.

REFRIGERATING PLANT.

Two Allen dense-air ice machines, of one ton per day capacity each, are installed, having an 8×8 steam cylinder.

ELECTRIC PLANT.

The dynamo room contains three 32-kw. General Electric generating sets delivering direct current at 125 volts. The driving engines are cross-compound vertical, $7\frac{1}{2} \times 12 \times 8$, and run at 400 r. p. m. There is a separate dynamo condenser of 200 square feet of cooling surface having a combined air and circulating pump, $6 \times 8 \times 8 \times 12$. The switchboard is located in the dynamo room.

The following electric auxiliaries are installed:

4 30-H.P. compound-geared deck winches.
3 5-H.P., 8,000-cubic feet hull-ventilation fans.
5 $1\frac{3}{4}$-H.P., 2,500-cubic feet hull-ventilation fans.
1 $1\frac{1}{2}$-H.P., fresh-water triplex pump, 30 gallons per minute.
1 1-H.P. dough mixer.
1 10-H.P. workshop motor.
1 2-H.P. dish washer.
1 $\frac{3}{4}$-H.P. potato peeler.
6 $\frac{1}{4}$-H.P. portable ventilating sets.
6 $\frac{1}{6}$-H.P. bracket fans.
30 $\frac{1}{12}$-H.P. desk fans.
2 60-inch searchlights.
1 80-H.P. torpedo air compressors.
4 3-H.P. ammunition hoists.
22 arc lights.
778 16-candlepower incandescent lights.

Complete interior communication systems, including a telephone central station in chart house, with 18 telephones, are installed.

Wiring is installed, partly in conduit and partly open, on porcelain insulators.

STEERING GEAR.

A Williamson steam-steering engine drives the usual Navy standard right-and-left-hand screw gear. There are two hori-

zontal steam cylinders, 12×10. The controlling valve of the engine is operated by wire-rope transmission from steering wheels in chart house and on bridge, and a steering wheel is mounted on the engine. Hand-steering wheels are also installed in the steering-engine room.

ANCHOR ENGINE.

The windlass has two wildcats on vertical shafts driven by two wormwheels meshing with one worm on an extension of the engine crankshaft. The engine is of the double vertical type.

MISCELLANEOUS AUXILIARIES.

2 engine-room fire and bilge pumps, Blake vertical simplex, 10×8½×12.
1 reserve feed-tank pump, Blake vertical simplex, 3½×4×4.
3 fireroom fire and bilge pumps, Blake vertical simplex, 12×8×12.
3 ash hoists, Williamson, 4½×4½.
3 hydraulic ash ejectors, one in each fireroom.

POWER OF AUXILIARIES.

While at the dock the various auxiliaries were indicated and curves of I.H.P. plotted. The following are here given: Fig. 5, forced-draft fans; Fig. 6, main circulating pump; Fig. 7, dry vacuum pump; Figs. 8 and 9, hotwell pump. All other auxiliaries are the same as those installed on the U. S. S. *Birmingham*, curves for which are given in paper by Commander Theo. C. Fenton, in "JOURNAL A. S. N. E.," Vol. XX, No. 3, August, 1908, and the same curves were used on the *Salem*.

BUILDERS' TRIALS.

Before leaving the builders' yard four complete sets of propellers were made. All except the No. 1 set were of the cast-solid type. Each set was tried by a run across Massachusetts Bay and a standardization on the Provincetown measured

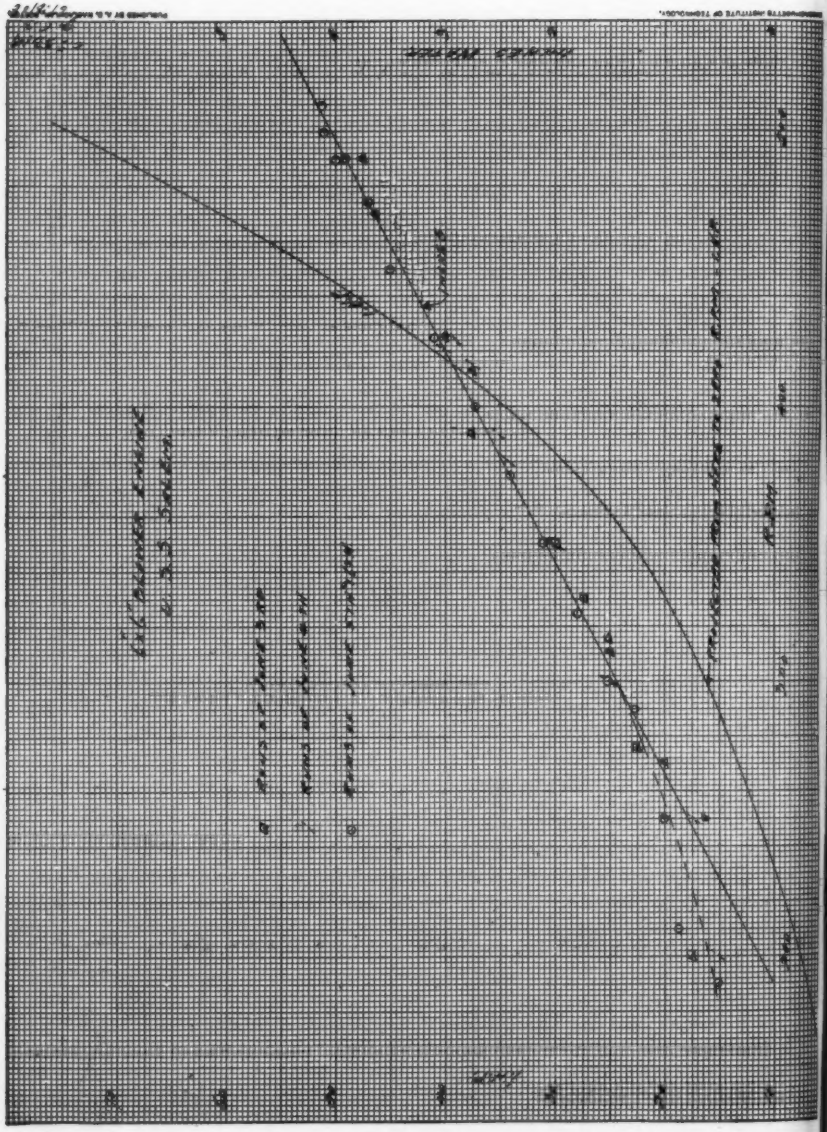


Fig. 5.

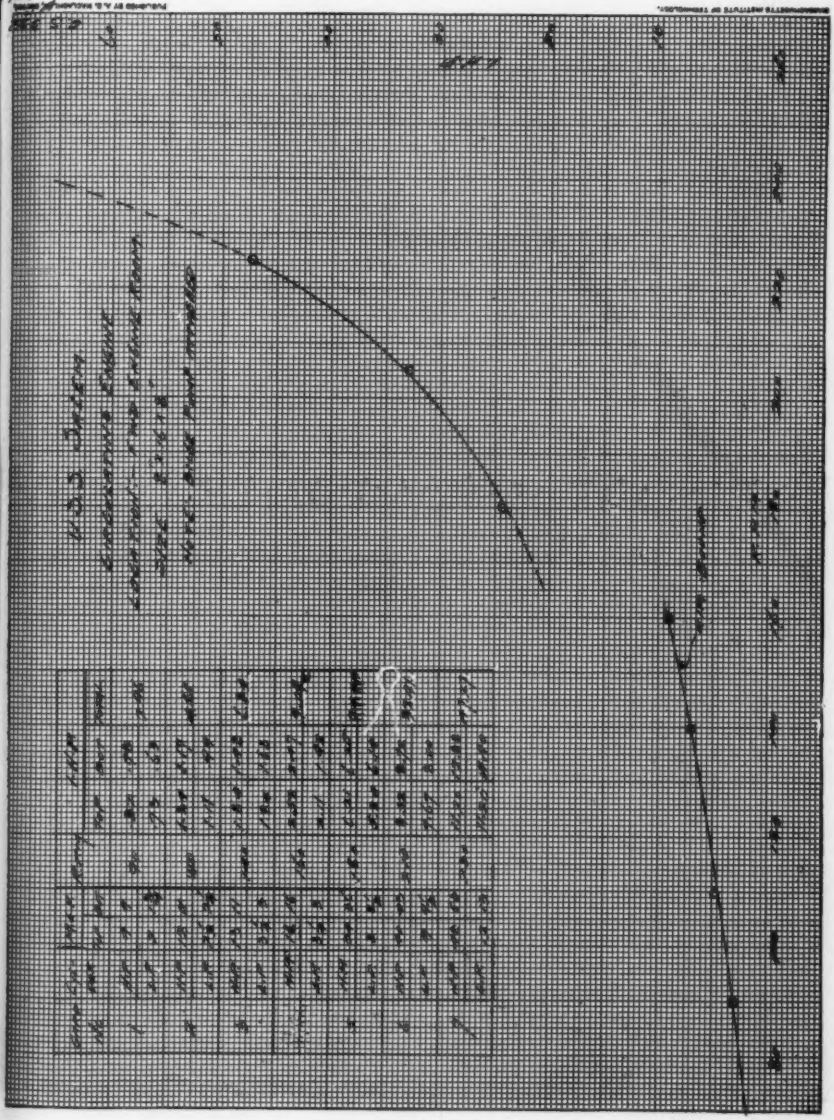


Fig. 6.

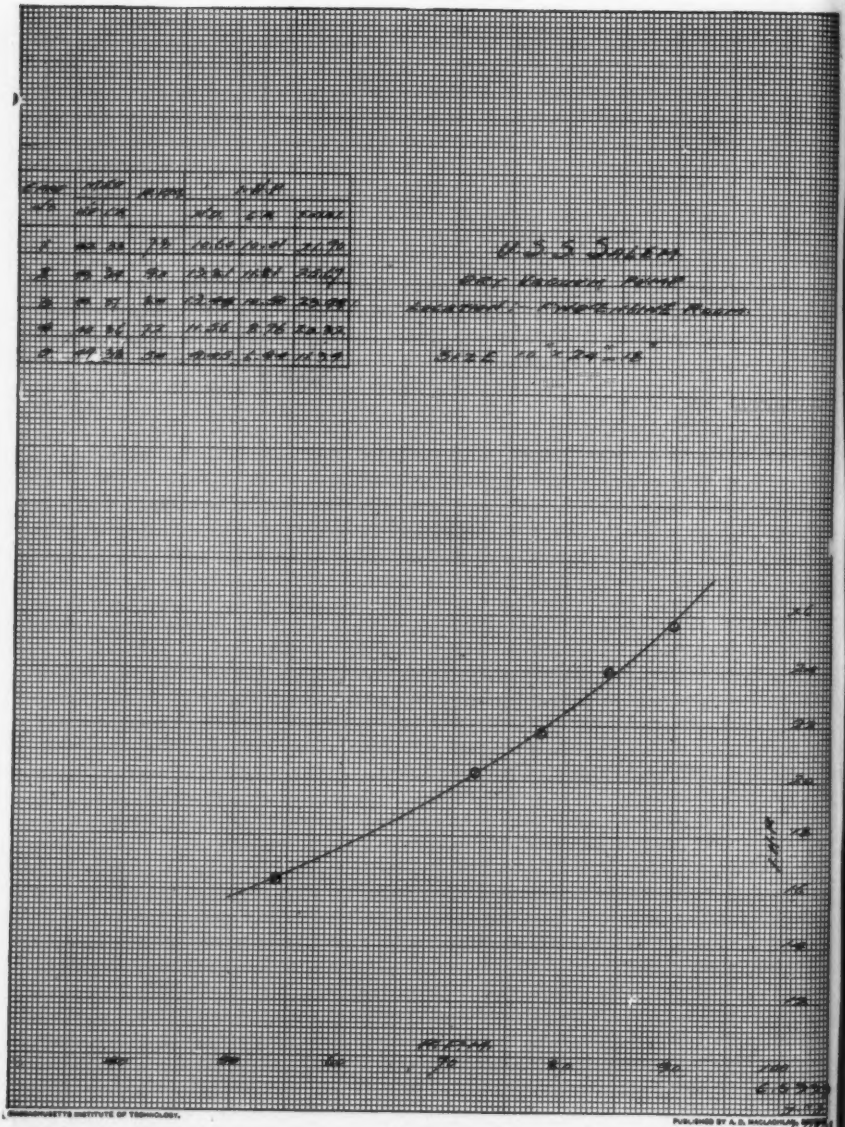


Fig. 7.

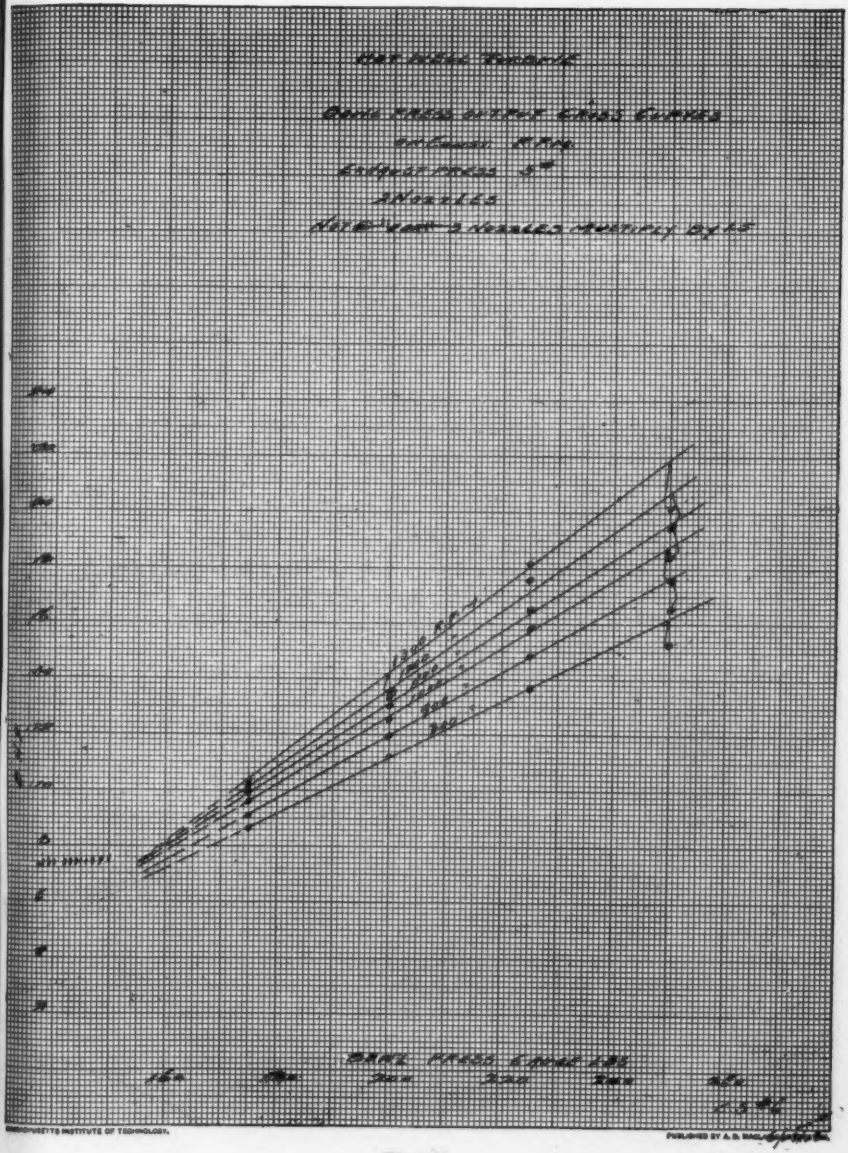


Fig. 8.

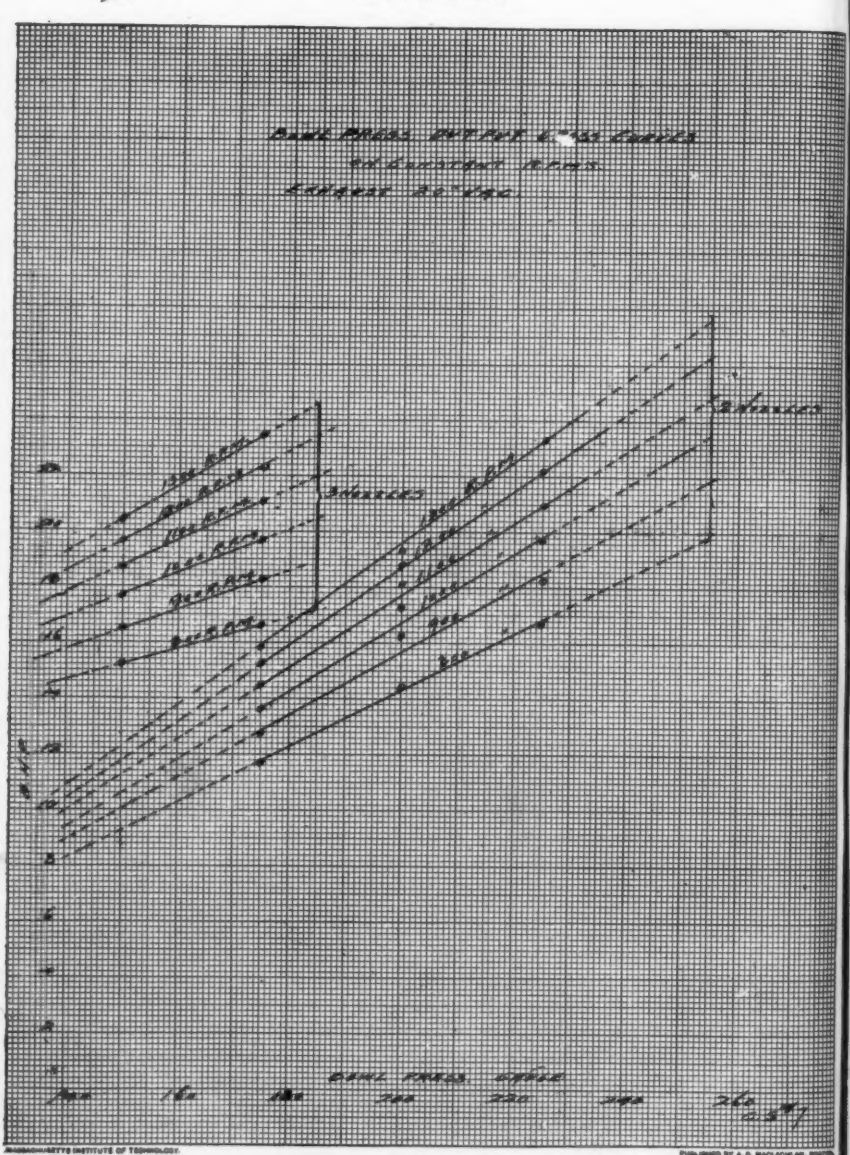


Fig. 9.

mile. The vessel returned to the Boston Navy Yard after each trial, and went into drydock to have the propellers changed. The second set tried proved to be the best, and was refitted after the completion of the trials.

The vessel left the builders' yard on June 3, 1908, and completed the four trials on June 12, 1908, in an elapsed time of nine days, including two days spent in drydock for cleaning and painting.

Immediately after these trials request was made to the Department for official trial. The Board of Inspection and Survey came on board the vessel at Rockland on June 22d, and all the official trials were finished July 1st, in an elapsed time of nine days.

OFFICIAL TRIALS.

The vessel was first standardized on the measured mile at Rockland, then the four-hour full-speed run was made, followed by the twenty-four-hour run at 12 knots, and finally the twenty-four-hour run at 22½ knots.

STANDARDIZATION.

The mile runs were made in groups of three, at approximately 12, 14, 16, 19 and 23 knots, and a group of five runs at 26 knots. Each group of three runs was averaged by multiplying the middle run by two and dividing the total by 4; the five high runs were averaged similarly in groups of three and the mean of these two averages taken. The knots-revolution curve was drawn through these averaged points.

The brake horsepower developed by the turbines was measured by Denny-Johnson torsion meters, operated by the Trial Board, and also by a Fottinger torsion meter, operated by the contractors. These two measurements check each other within 2 per cent. at full power; the Fottinger meter readings are used in this report.

The observed results in each run are given in the following table:

STANDARDIZATION RUNS, JUNE 23, 1908.

Run No.	Knots.	Nozzles open.	R. P. M.			Main, Starboard.	Steam port.	Chest.		First stage.		Exh. shell vacuum.		Condenser vacuum.		Torsion meter reading.
			Stbd.	Port.	Mean.			Stbd.	Port.	Stbd.	Port.	Stbd.	Port.	Stbd.	Port.	
1	14.60	3	192.8	195.9	194.3	251	254	230	250	11.5	13.0	28.8	27.8	28.9	28.2	2.59
2	13.33	3	187.5	193.0	190.2	263	264	208	235	11.5	13.0	28.8	28.3	28.9	28.5	2.60
3	14.06	3	185.0	194.0	189.5	265	265	201	210	11.5	13.0	28.8	28.1	28 9	28.5	2.53
4	15.48	4	223.2	225.3	224.2	260	268	246	265	17.5	17.0	28.8	28.2	28.8	28.6	3.73
5	16.86	4	223.3	219.1	221.2	250	250	237	250	18.0	18.0	28.8	28.0	28.8	28.3	3.72
6	15.319	4	223.1	223.4	223.2	263	256	246	254	18.0	19.0	28.6	27.7	28.9	28.2	3.75
7	26.201	19	368.5	366.7	367.6	265	262	260	253	83.0	76.0	27.2	27.2	28.2	28.1	11.84
8	25.193	19	379.0	377.1	378.0	258	257	255	250	92.0	84.0	27.0	27.0	28.1	28.1	12.68
9	26.886	20	383.3	381.6	382.4	263	260	259	250	97.5	84.0	26.9	26.9	28.1	28.0	13.33
10	25.334	20	382.6	381.1	381.8	259	255	254	248	95.0	88.0	26.6	27.0	27.8	28.0	13.08
11	26.608	20	377.5	377.3	377.4	255	249	255	247	93.0	87.0	27.3	26.9	28.1	28.0	12.66
12	22.486	11	315.4	327.5	321.4	266	265	245	265	50.0	52.0	27.4	27.6	28.1	27.6	7.48
13	23.407	11	314.2	317.8	316.0	268	270	242	243	49.0	48.0	28.6	27.0	28.2	27.5	7.60
14	21.752	11	311.4	308.7	310.0	255	253	230	245	47.0	51.0	28.0	27.3	28.3	27.8	7.56
15	19.945	7	266.1	269.6	267.8	260	265	235	245	30.0	34.0	27.2	27.5	27.4	27.6	5.16
16	18.907	7	264.2	270.6	267.4	253	253	232	250	29.8	33.0	27.4	27.5	27.5	27.6	5.14
17	19.262	7	263.2	261.1	262.2	242	248	239	245	29.8	31.0	28.6	25.9	28.7	26.1	5.32
18	11.956	3	169.8	168.1	168.9	270	272	181	190	11.5	11.5	28.5	28.0	28.6	28.2	2.13
19	12.27	3	166.9	163.2	165.0	234	236	177	190	11.0	11.5	28.5	27.7	28.5	28.0	2.29
20	12.30	3	171.4	173.2	172.3	252	230	177	208	11.0	12.5	28.6	27.5	28.5	27.7	2.23

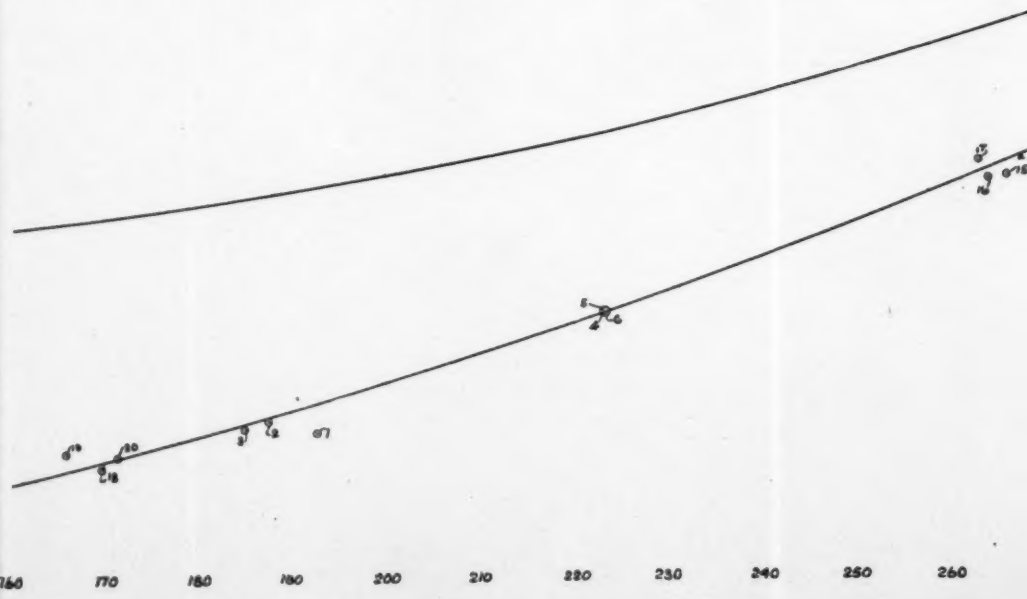
OFFICIAL

ROCKLA

DISP

TORSION M

B.H.P.



U.S.S.SALEM.

FICIAL STANDARDIZATION RUNS

ROCKLAND MAINE. JUNE 23, 1908

DISPLACEMENT 3745 TONS

RSION METER READING, ST'B'D SHAFT

B.H.P. = 1.985 x R.P.M. x METER READING

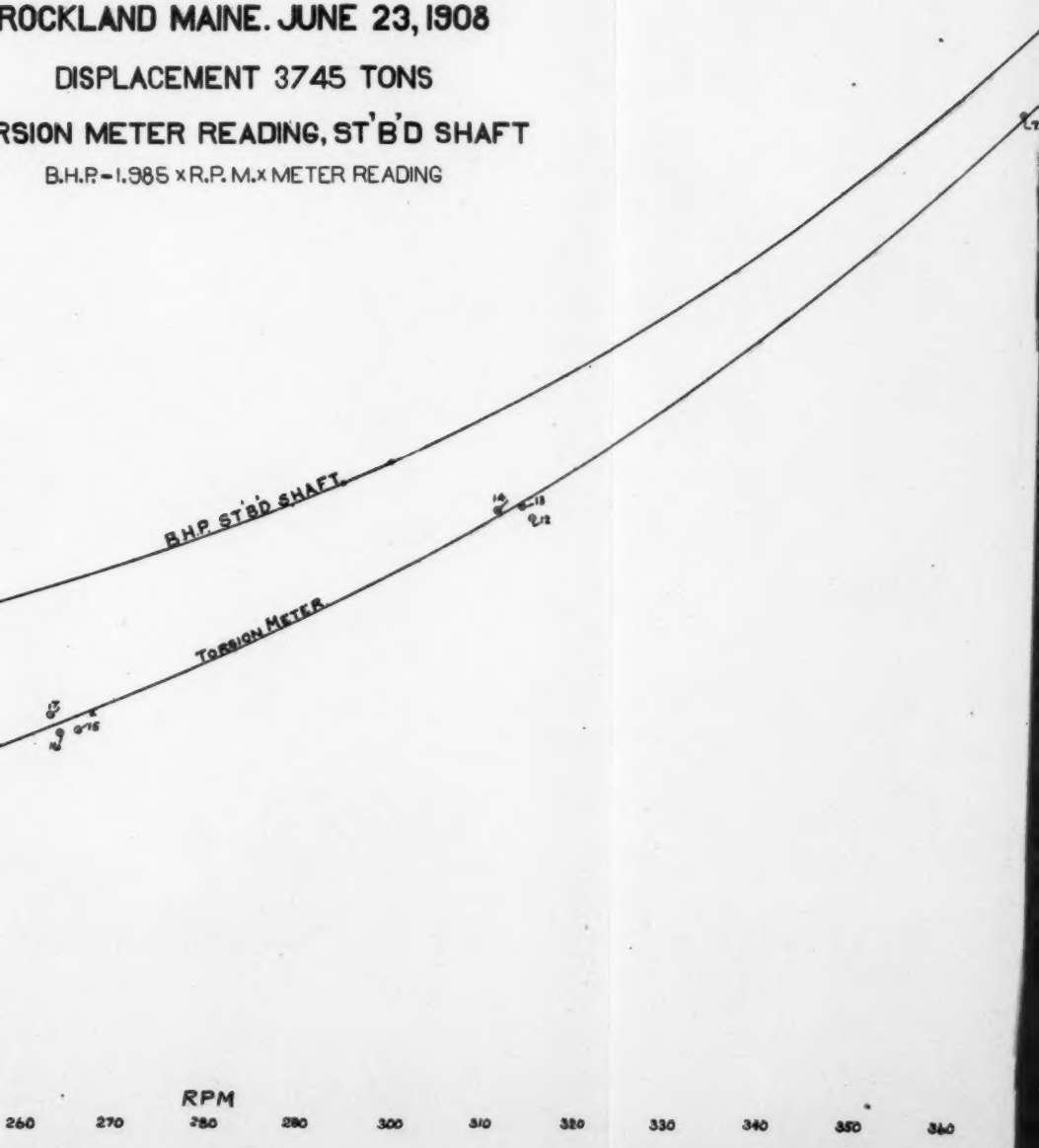


Fig. 10.

U.S.S. SALEM.

OFFICIAL STANDARDIZATION RUN

ROCKLAND MAINE. JUNE 23, 1908

DISPLACEMENT 3745 TONS

TORSION METER READING, ST'B'D SHAFT

B.H.P. = 1.985 × R.P.M. × METER READING

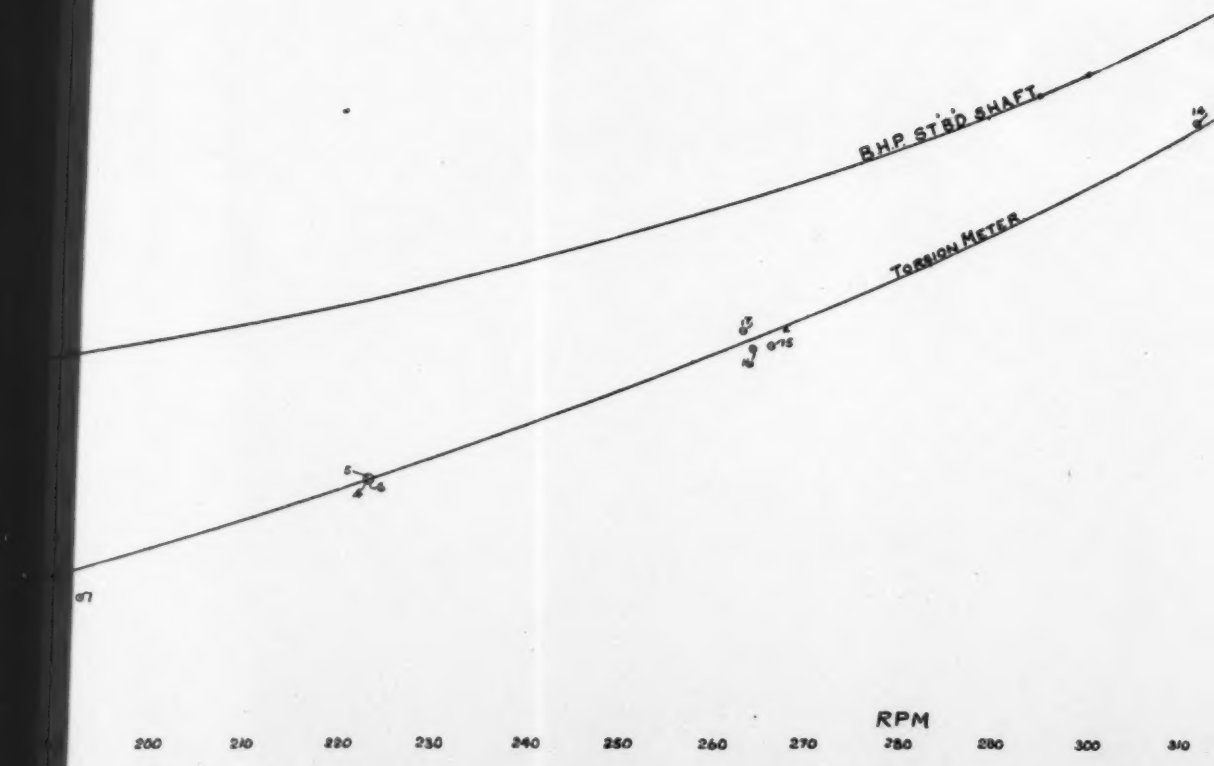
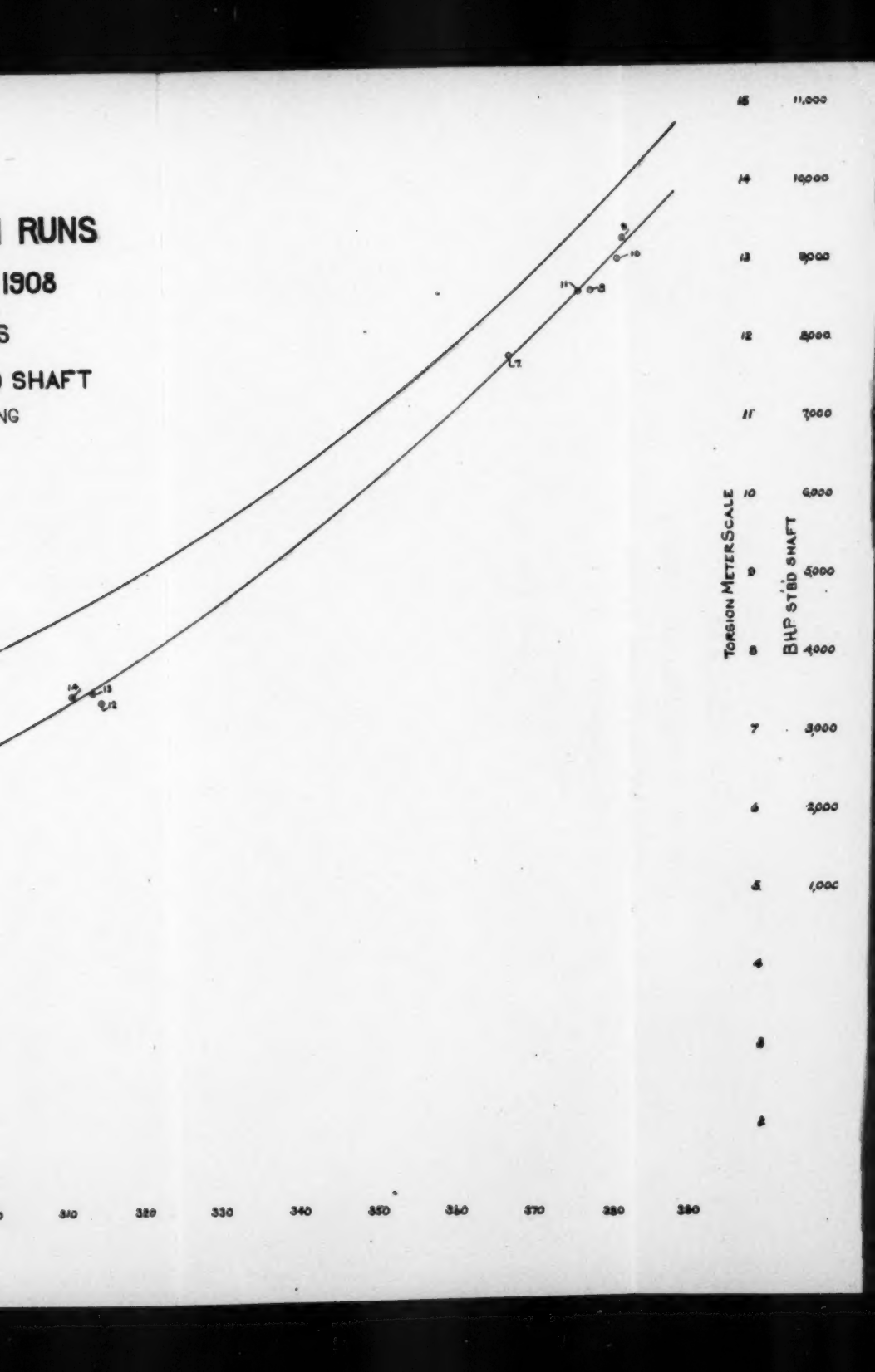


Fig. 10.


RUNS
1908
S
SHAFT
NG
TORSION METER SCALE
BHP STBD SHAFT
15
14
13
12
11
10
9
8
7
6
5
4
3
2
11,000
10,000
9000
8000
7000
6000
5000
4000
3000
2000
1,000
340
330
340
350
360
370
380
390

U.S.S.SALEM.

OFFICIAL STANDARDIZATION RUNS

ROCKLAND MAINE. JUNE 23, 1908

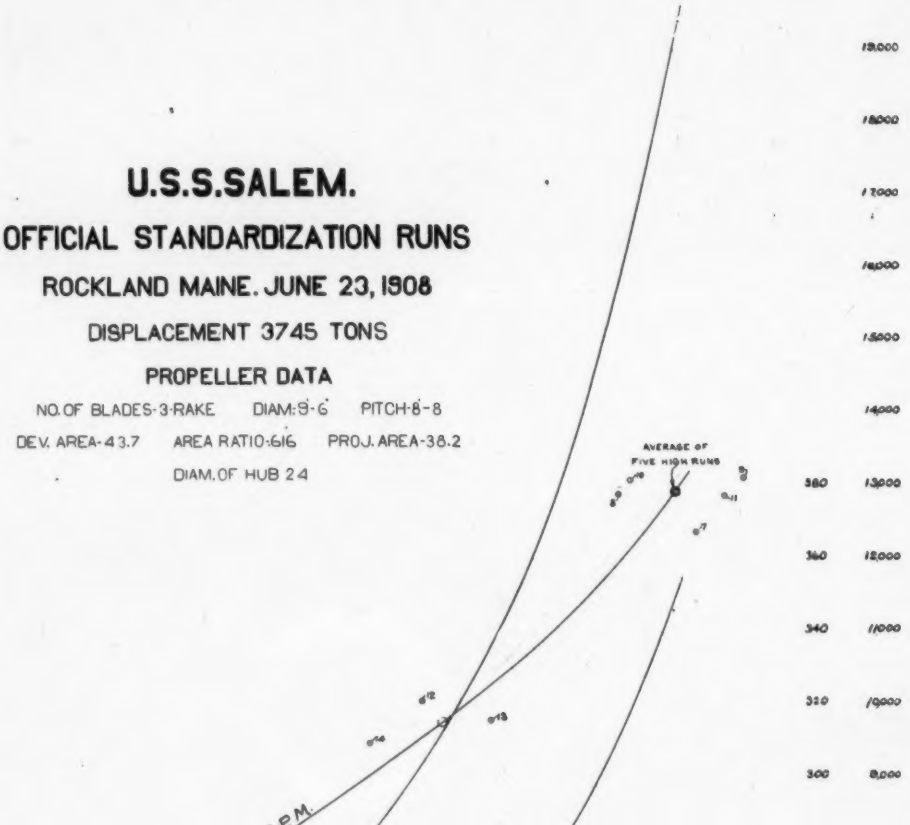
DISPLACEMENT 3745 TONS

PROPELLER DATA

NO. OF BLADES-3-RAKE DIAM:9'-6" PITCH-8'-8"

DEV. AREA-43.7 AREA RATIO:616 PROJ. AREA-38.2

DIAM. OF HUB 24



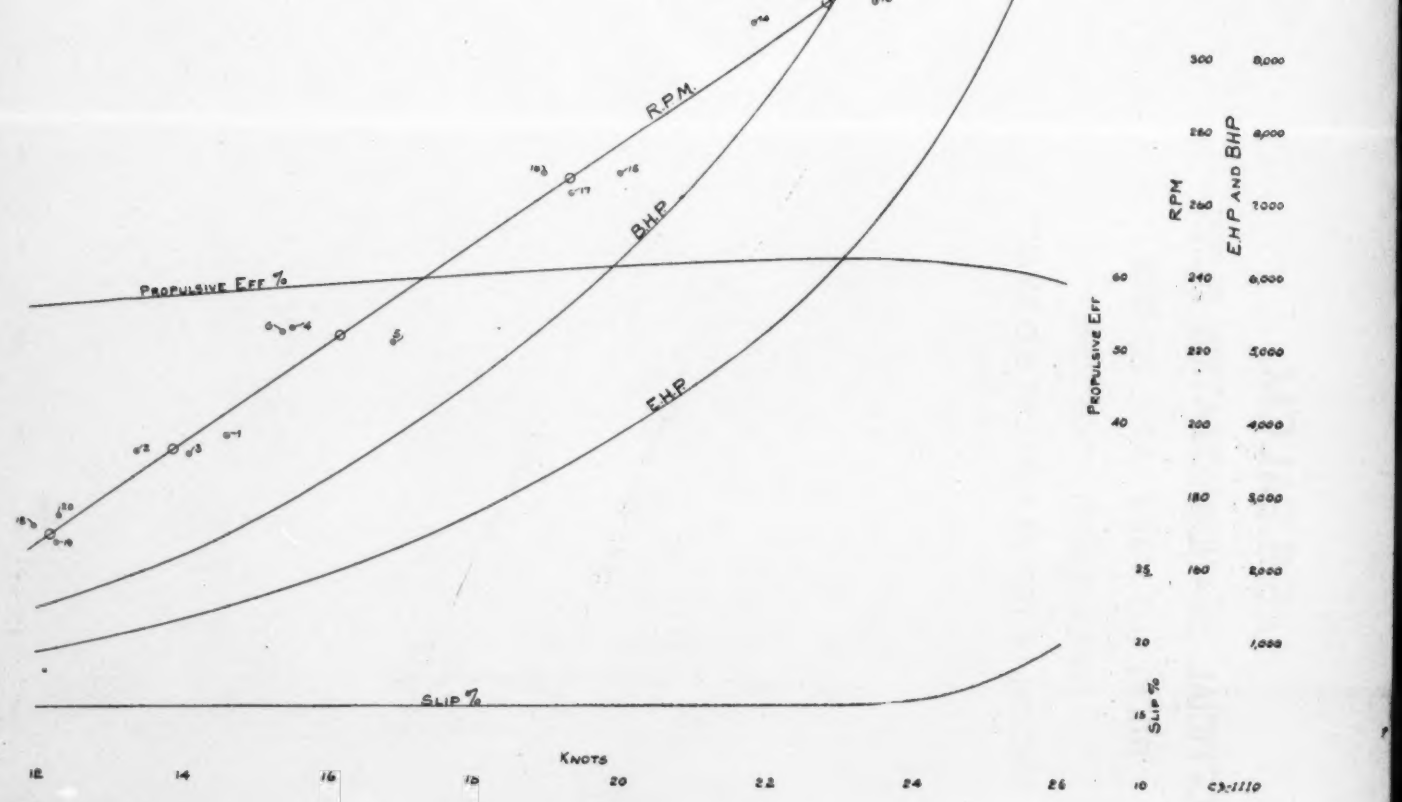

RPM
BHP
EHP
PROPULSIVE EFF %
SLIP %
KNOTS
PROPULSIVE EFF
RPM
E.H.P AND B.H.P
SLIP %
60
50
40
25
20
15
300
280
260
240
220
200
180
160
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
12
14
16
18
20
22
24
26
10
C3-1110

Fig. 11.

The above results are plotted as curves in Figs. 10 and 11, the effective H.P. curve being taken from the model tank results and is without appendages.

RUNS IN OPEN SEA.

After the standardization the three different straight-away open-sea runs as previously given were made, and the speed of the vessel on each taken from the average revolutions of the propellers on the above standardization curve of knots and revolutions.

The following table gives the final average results of the three runs:

Item.	4-Hour, full power.	24-Hour, 22½ knots.	24-Hour, 12 knots.
Date, 1908	June 25.	June 26, 27.	June 30.
Average speed of vessel	25.946	22.53	11.93
Pressures:			
Boilers, pounds, gauge	274.5	255.7	219.6
Throttle valves, pounds, gauge	258.5	246.1	212.0
Steam chest, pounds, gauge	253.0	240.5	162.0
First stage shell, pounds, gauge	77.0	49.0	5.1
Exhaust chamber, inches mercury	26.7	28.4	27.9
Condenser, inches, mercury	27.8	28.65	28.7
Air pressure in fireroom, maximum	4.7	2.6	1.1
average	4.1	2.01	0.84
Temperatures, degrees Fahrenheit:			
Injection	56.5	57.0	58.0
Discharge	98.0	84.8	81.5
Hotwell	97.0	76.2	68.0
Feed water	178.0	180.6	181.0
Engine-room working platform	90.0	92.0	91.0
Firerooms working level	100.0	92.0	97.0
Smokestacks	764.0	602.0	537.0
Outside air	71.0	68.0	68.0
Revolutions, or double strokes, per minute:			
Main turbines	378.3	312.5	164.1
Dry-air pumps	68.0	50.5	40.5
Hotwell pumps	1,329.0	1,320.0	1,316.0
Circulating pumps	365.0	275.0	125.5
Main feed pumps	34.0	25.5	16.0
Dynamo engines	400.0	400.0	400.0
Forced-draft blowers	512.0	345.0	252.0
Distiller-circulating pumps	16.0	34.0	...
Slip of propellers	20.28	16.17	15.48

Item.	4-Hour, full power.	24-Hour, 22½ knots.	24-Hour, 12 knots.
Power:			
Main turbines, B.H.P.	19,200.0	9,340.0	1,360.0
Dry-air pumps, I.H.P.	39.0	32.0	28.0
Hotwell pumps, I.H.P.	49.0	48.0	31.0
Circulating pumps, I.H.P.	371.0	196.0	25.0
Main feed pumps, I.H.P.	143.0	96.0	26.0
Total engine auxiliaries, I.H.P.	602.0	372.0	110.0
Dynamo engines, I.H.P.	35.0	35.0	35.0
Forced-draft blowers, I.H.P.	450.0	126.0	36.0
Distiller-circulating pump, I.H.P.	5.0	23.0	6.0
Fire and bilge pump, I.H.P.	...	1.0	2.0
Steering engine, I.H.P.	5.0	5.0	5.0
Total I.H.P. all auxiliaries.	1,097.0	562.0	194.0
Equivalent I.H.P. of main turbines	21,120.0	10,274.0	1,496.0
Grand total all I.H.P.	22,217.0	10,836.0	1,690.0
Coal:			
Total coal burned per hour, pounds.	38,502.0	18,485.0	4,051.0
Per square foot of grate per hour, pounds.	55.32	26.56	17.46
Per B.H.P., main turbines, pounds.	2.01	1.97	2.98
Per I.H.P., main turbines, per hour, pounds.	1.81	1.78	2.68
Total I.H.P. per hour, pounds.	1.73	1.70	2.40
Knots per ton of coal	1.51	2.73	6.6
Water:			
Pounds per hour per B.H.P., main turbines only	14.74	15.85	26.13
General:			
Mean displacement, tons	3,751.0	3,753.0	3,760.0
Trim, inches	5¼ by stern	8¼ by stern	$1\frac{1}{16}$ by bow
Course direction	...	E.N.E.	E.N.E.
	W.S.W.	W.S.W.	W.S.W.
Wind direction	W.S.W.	Variable	Variable
Force	2	2 to 3	Light
Sea	Smooth	Smooth	Smooth

SPEED BY HOURS ON A FOUR-HOUR RUN.

1 hour.....26.00 knots.
2 hours.....26.01 knots.
3 hours.....25.98 knots.
4 hours.....25.85 knots.

In the above table the equivalent I.H.P., corresponding to the actual B.H.P., of the main turbines as measured, is based on 10 per cent. of friction in an equivalent reciprocating engine.

The water rate per B.H.P., of main turbines above given was measured on the starboard turbine only, by means of temporary measuring tanks installed by the contractors, and the results given are for the portions of the runs when the boilers were steaming quietly without priming.

On account of reserve feed water, taken on in Boston Harbor after the end of the four-hour trial, being impregnated with cement sediment due to tank of the water barge being newly cemented, the boilers primed considerably during the later trials. This priming caused no trouble in the operation of the turbines, which simply slowed down somewhat whenever any water came over.

The coal used gave the following analysis:

Moisture, per cent	3.04
Volatile matter, per cent	18.59
Fixed carbon, per cent	70.94
Ash, per cent	7.43
	100.00
Sulphur	.58
B. T. U. per pound	14,227.0

MANEUVERING TRIALS.

While going at full speed ahead the engine telegraphs were suddenly thrown to full speed astern with the following results:

Begin to back: Port, 42 seconds; starboard, 54 seconds.

Full speed astern: Port, 1 minute 30 seconds; starboard, 1 minute 53 seconds.

From full speed astern to full speed ahead the results were:

Begin to go ahead: Port, 15 seconds; starboard, 25 seconds.

Full speed ahead: Port, 1 minute 4 seconds; starboard 1 minute 33 seconds.

COMPARISON TO RECIPROCATING ENGINE.

The following table compares the principal economy results of the *Salem* with the corresponding figures of the *Birmingham*, which is a sister vessel and of the same construc-

tion in every respect, except that the main propelling engines are of the usual reciprocating type.

Item.	*Salem.*	*Birmingham.*	*Salem.* Gain pr. ct.
Coal per equivalent I.H.P. of main engine per hour, pounds:			
At full power	1.81	1.92	6.07
22½ knots	1.78	1.91	7.3
12 knots	2.68	2.89	7.83
Knots per ton of coal:			
At 22½ knots	2.73	2.47	9.52
12½ knots	6.6	5.965	9.62

It is to be noted that in the above comparison the *Birmingham* developed on the full-power trial an average of 15,540 I.H.P., while the *Salem* developed 19,200 B.H.P., or about 35 per cent. more power, and even at this extra forcing had the better economy. It is also especially noticeable that at the low cruising speed of 12 knots the turbine vessel showed an increased economy gain.

NOTES.

EXTRACT PROM ANNUAL REPORT OF THE CHIEF OF BUREAU OF STEAM ENGINEERING, FOR FISCAL YEAR 1908.

Instruction of Young Line Officers in Engineering.—It is greatly to be deplored that the important and satisfactory work of the Bureau's school for instruction in engineering had to be discontinued for want of officers to be instructed. No new officers have been ordered during the past year and the very satisfactory organization, which had been almost perfected during its three years of existence, has been broken up. Although the number of officers under instruction was always too small, it was infinitely better to instruct these few than none at all.

The need for line officers specialized in engineering has greatly increased and will continue to increase, and one year at least for making these specialists has been lost.

The necessity of officers specializing in engineering was clearly shown in the report for 1907 of my predecessor. I can add to that only my hearty approval of the statements made there, and the firm conviction that the sooner the course of instruction is reestablished the better will the needs of the Navy be satisfied and its efficiency be increased.

It is urgently recommended that the Bureau's course of instruction of young line officers be not only resumed, but that the number of officers detailed for instruction be increased. To interrupt this method of imparting the special engineering knowledge so necessary to the line officer in a modern navy would appear to be a step backward, and, if continued, one that will result in serious detriment to the technical training of this body of officers.

That the experience and knowledge of the few remaining officers for engineering duty only should be utilized in instructing those line officers who are to take over their work

would seem to need no argument, yet the practice in the Navy, except in a very few cases, is directly the opposite. In navy-yards, at inspection duty, and in designing, the officers for engineering duty only practically do the duty alone, but few young officers being assigned to learn the work under them, and to receive the benefit of their experience and knowledge.

Consolidation of Shops at Navy Yards.—During the past year all pattern, copper and foundry work at the larger eastern yards has been consolidated under this Bureau, and the system has now been in operation long enough to show that it will result in increased efficiency and in economy of operation to the Government, and that after the various shops have been thoroughly arranged to meet the new conditions there will be still further improvement in this direction. It is therefore recommended that the system of consolidation adopted for the eastern yards be applied also to those of the west coast.

Officers for Engineering Duty.—It is with regret that I have to invite the attention of the Department to the unsatisfactory condition as regards the number of officers assigned to duty under this Bureau. This condition was commented upon in the reports of my predecessor, and suggestions made for its improvement, but without avail. The condition is rapidly becoming worse, and the Bureau is now seriously handicapped in its work by the lack of officers for engineering duty, and also by the lack of experience of some of the officers who have been so assigned. It is recognized that the limited number of officers available for the general duties of the line is responsible for this condition, but engineering in the Navy has now reached such a point that two things must be done: (1) for temporary relief, at least twenty officers of the grades of lieutenant-commander and lieutenant should be ordered at once to shore duty connected with this Bureau, and (2) a fixed policy should be adopted of assigning permanently a certain number of officers to engineering duty only, such assignment to begin upon entering the list of lieutenants, and officers so assigned to perform shore duty only, after reaching the grade of commander.

There is a vast field for improvement in the administration of the huge machinery installations in the United States Navy; there are many problems of efficiency and economy which can be solved, notably coal and oil consumption; the reduction of expense of a ship coming to a navy-yard for repairs; by a closer and better supervision of machinery details, and which can be gained by a higher and better skilled technical knowledge, and lastly greater economy in navy-yard management. The opportunities for improvements in the field above mentioned can be obtained only by a more extended performance of engineering duty by officers below the rank of commander of the branch to which engineering belongs, viz: the line. Especially must some action be taken in the administration and performance of those shore duties required by law in the execution of engineering contracts for machinery of new vessels under construction, for the large volume of repair work at our navy-yards, and for the inspection of material.

That immediate assistance from the general line for engineering duty on shore is absolutely necessary will appear from the following statement of the duties which must be carried on, and the fact that there are now only six line officers, in addition to the thirty-four for engineering duty only, engaged in these duties.

With these requirements confronting the Bureau, the attention of the Department is invited to the existing conditions:

The Navy-yards.—During the past year the engineering departments of the several navy-yards have suffered seriously from lack of officers. In important yards with numbers of vessels under repairs, the head of department is without a single commissioned assistant. In the event of extended illness there is a decided falling off in the discipline and conduct of work during the enforced absence of the head, without a skilled successor to take up and continue properly the thread of work. The engineering work of officers at navy-yards includes the making of estimates for repairs; deciding upon their necessity; preparing designs for alterations and repairs,

and supervising and conducting the work when authorized, both on shore and on the ships.

For the proper performance of these duties there should be a sufficient detail of commissioned assistants to the senior engineer officer of the navy-yard to insure that technical supervision over details without which work will not be properly done nor its cost kept within estimates. That such assistance has not been furnished from young line officers may be inferred from the fact that but four line officers, other than those for engineering duty only, are now doing engineering duty at navy-yards.

Inspection of Machinery for Vessels Under Construction.—At ship-building yards the conditions are even worse, not a single young line officer being on duty there in connection with machinery, although the field is one of the best for instruction and development. The absence of such assistants renders the duties of the inspectors of machinery particularly onerous and their inspection less efficient, and throws on the over-burdened bureau staff a mass of detail which should be disposed of at the building yard. Before the passage of the personnel law, it was the invariable practice to detail one or more junior officers as assistants to the inspector of machinery of vessels under construction. These officers were always detailed with a view to their assignment to these ships upon completion, and by close personal contact with the machinery during the final stages of its assembly on board, and by their presence and observation during the preliminary and full-speed trials, acquired a mass of information about the machinery and the ship in general that was of incalculable value to the Government during the ship's "shaking down" and in the succeeding periods of active service.

Inspection of Material.—Of equal importance with the work at navy-yards and private shipbuilding establishments is that of the inspection of the material that enters into the construction of our ships. While the number of officers engaged in the duty of material inspection is yearly decreasing, the field of material production for naval engineering purposes is con-

stantly enlarging. My predecessors in office, in their annual reports, have recommended the detail of junior officers of the line for this inspection duty, in order that they might have the benefit of the experience of the older officers now on inspection duty, all of whom are well qualified by experience to instruct younger officers in this important duty. This recommendation I now most earnestly repeat.

The Bureau knows that the quality of the engineering material furnished the Navy has been raised through the development of the present system of inspection, and it is urged that this system be not allowed to lapse or to fall below its present high standard. To maintain this material inspection as it should be maintained, young blood is absolutely essential, and the Bureau respectfully and earnestly urges the detail of junior line officers for this duty. This requested detail of young officers should be made at once, because the number of qualified inspectors is decreasing every year, and but for the retention on inspection duty of several retired officers there would be only two commissioned officers to direct the inspection work of eight districts. At present one retired officer has charge of two important districts and another has four districts in his charge. It is evident that it is not possible, in such cases, for the naval inspector to keep that close personal supervision of the work that is so necessary to success. Consolidation of districts would not help matters at all, since then the responsible head becomes merely a traveling overseer, and practically all the actual work of inspection must be left to assistant inspectors who, in many cases, are not familiar with the object for which the material is to be used, a system which the Bureau does not believe to be desirable. The young line officer should be as well acquainted with the manufacture of the materials that go to make up the machinery of our battle ships as he must be with the design and management of that machinery. In fact, the prime requisite for the successful engineer is to know the qualities of the materials he is to use, whether these materials are to be used in ships, guns, armor or machinery. It is equally important that the line officer, the man who is

to manage the finished product, should know the capabilities and the limitation of his materials. This knowledge can be obtained only by actual duty in the inspection of material as it comes from the forge, the foundry, the plate mill or the tube mill.

The Bureau of Steam Engineering.—The work of designing naval machinery, general supervision over repairs to naval machinery, the examination and supervision of machinery plans in detail submitted by contractors engaged in building government vessels, and the collection and arrangement of engineering data of the world's progress in naval engineering, is done at the Bureau of Steam Engineering.

The work of designing is done under the supervision and direction of line officers for engineering duty only, who were members of the former engineer corps, and who have had the benefit of a course in designing machinery at the Naval Academy, with many years of valuable experience afloat in the management of machinery, and on shore in its construction. It would seem that, as the time for this duty to pass to younger officers is rapidly approaching, it is absolutely necessary that a number of these younger officers should be detailed for duty in the Bureau, in order that they may become familiar with the methods pursued and acquire knowledge of this important part of their profession. There are now only two line officers on duty in the Bureau, other than those for engineering duty only, and, from force of circumstances, one of these is engaged in work other than that connected with design.

The engineer-in-chief, from an extended acquaintance with the young line officers of our Navy in their academic instruction, as well as with their practical engineering training both ashore and afloat, is fully cognizant of the fact that they can become good engineers. While the Naval Academy, with its excellent engineering plant for instruction, probably unequaled in any engineering school in the world, is attending to the academic engineering training, and within its limits, to the practical education also, there is yet much to be done in that

post-graduate training which every technical man must receive in the practical and essential details of his profession. Part of this post-graduate training can be obtained, with a resulting advantage to the Government, and enable the Bureau to carry on the authorized duty on shore, by the assignment of the number of line officers asked for above.

Some of the most important duties performed under this Bureau have been enumerated, as stated above, in order to impress upon the Department the necessity for providing now an adequate number of officers properly to perform it. It is and always has been the opinion of this Bureau that the greatest efficiency results when the officers who design our machinery are also the ones who superintend its construction on shore and later its operation at sea, for thus only can they acquire that familiarity with the needs of the service which suggests at once the things to avoid as well as those to adopt. I think it will be generally admitted by officers of the Navy who have given close attention to the subject that the excellence of our ordnance, of our machinery, and of our electrical equipment has been due to the fact that the officers who inspected the material and superintended the construction on shore were the same ones who afterwards at sea supervised the operation of these parts of the ships' equipment. And I believe that if this system is not fully carried out, there will be deficiency in that branch in which such a system is lacking.

That this system may be carried out in full, it is considered imperative that permanent assignment of officers to engineering duty shall be made after a certain length of service. That such permanent assignment was contemplated by the personnel board of 1906, and of which the present Assistant Secretary of the Navy was president, is evident from paragraph 16 of their report, which provides for "those who are now or may become eligible for engineering duty," and from paragraph 23, which reads: "The board, while in favor of the amalgamation of the line and former engineer corps, as provided by the present personnel law, in a general sense, desires to express the opinion that experience shows that some specialization for

the design and inspection of machinery should be created." Further, from the letter of the then Assistant Secretary of the Navy transmitting the report of the personnel board of 1897, and from the hearings before the Committee on Naval Affairs of the House of Representatives, Fifty-fifth Congress, second session, which resulted in the act of March 3, 1899.

In his letter of transmittal, the then Assistant Secretary said:

"The building of engines, like the building of guns or torpedoes, must be done by special officers selected or detailed for the purpose."

And again:

"This is an age of specialization. * * * In time it may very possibly prove desirable to differentiate, less by law than by departmental custom, among the officers at sea, so as to employ each principally along the lines for which he shows the most aptitude, but they must remain line officers, the major part of whose duties are identical; and the engineer must differ from his fellows only in the same manner as the navigator or ordnance expert does."

In the hearing before the naval committee, the then Assistant Secretary of the Navy said:

"My own view is this: That we should, within the Department, by detail, directly reverse the policy that has for some time obtained there, of having every man in turn do every duty, the fact that he has perfomed the duty being considered a reason why he should never perform it again; and, on the contrary, we should, as far as we can, differentiate men after they have passed through the first eight or ten years."

It is this differentiation that the Bureau earnestly recommends for the consideration of the Department. The plan to accomplish this is simple, will cost no money, and requires legislation only so far as to amend the personnel act as follows:

"*Provided,* That the provisions of section 5 of the act of March 3, 1899, shall apply to such line officers as may be assigned to permanent engineering duty by the Secretary of the Navy."

A number of officers have shown marked aptitude for engi-

neering duty, and are now ready and willing to be assigned to engineering duty only, if the opportunity is given them under the above-mentioned conditions. Without such a system, engineering in the Navy must fail, and any deficiency there means as much to the efficiency of the fleet as failure in guns or torpedoes.

LAUNCH OF SUBMARINE "C. 17."

This vessel, the first of the class to be built in one of the Royal Dockyards, was launched on the 13th ultimo at Chatham. The ceremony was of a private character, and the vessel herself had been built under conditions of close secrecy, the shipway being enclosed and all the workmen who have been engaged on her having been sworn not to divulge any information about her. Her dimensions are as follows: Length, 130 feet; beam, 13 feet 6 inches; with a displacement of 313 tons when submerged. The engines are to develop 600 I.H.P., which will give her a speed on the surface of 13 knots.—"Journal Royal United Service Institute."

ACCIDENTS TO SHIPS OF WAR.

A Parliamentary paper, giving the number of ships and other craft of war which have been in accidents since 1st January, 1901, has been issued by the Admiralty. The return states that during the period, 1st January, 1901, to 27th May, 1908, the number of His Majesty's ships and other craft of war which have been in accidents was 442. The number of His Majesty's ships and other craft of war which have been totally lost was 16, including the loss by fire of the *Forte*, coal depot. The loss of picket boat of the *Edgar*, the steamboat and pulling cutter of the *Vernon*, the gig of the *Defiance*, a submarine mining vessel, and the steam cutter *No. 219*, are excluded. The original cost of ships and other craft which have been totally lost, including guns and naval ordnance stores, was £1,951,974. The number of vessels which have

been in accidents, and which have been repaired during the years 1901 to 1906 was: in His Majesty's dockyards, 218; outside His Majesty's dockyards, 60. The number of lives lost as a result of accidents on board His Majesty's ships was 408. The annual amount of pensions and aggregate amount of gratuities awarded to the dependants of those who lost their lives were: pensions, £2,592; gratuities, £3,290.

FRENCH NAVAL NOTES.

The first-class battleship *Verité,* which conveyed the President of the Republic to Reval on his visit to the Tsar, arrived at Brest with the escorting ships of the squadron on its return from this duty on the 6th ultimo; Vice Admiral Boué de Lapeyrère, who has been in command, struck his flag on board the *Verité* the next morning and resumed his duties as Maritime Prefet of the port.

The first-class battleship *Iéna,* condemned for service after the disastrous explosion last year, is being repaired at Toulon to the extent of making her capable of floating, and to be used as a target. It is stated that the firing experiments will include (1) observation of the effects of projectiles fired at close range on the light armor and superstructure; (2) of the effect of bursting shells after penetration at long distances up to 6,000 meters. The program of firing will, however, be elaborated by a committee, to be presided over by Rear Admiral Auvert, composed of a capitaine de frégate, two engineers, a chef d'escadron of artillery, a captain of artillery, and two lieutenants de vaisseau.

In accordance with the recommendation of the Committee appointed to report on the proposal that the Ecole-Navale should be transferred from the *Borda* to a naval college to be built at Brest, Vice Admiral Boué de Lapeyrère (the Prefet Maritime) and a committee have been charged with the duty of selecting a site for the building. The naval school afloat dates back to the year 1827, when it replaced the naval college at Angoulême; thus history repeats itself.

Four thousand officers and men of the *Artillerie* and *Infanterie Coloniale* have been sent as reinforcements to Tonkin during the last few weeks, and it is stated a like number are to be sent towards the end of the present month.

On the 3d ultimo the new submarine *Turquoise* was launched from the Mourillon-Toulon yard, and is the last of the group being constructed at that yard; the other three vessels being the *Emeraude,* now attached to the 1st Channel Flotilla at Cherbourg, and the *Saphir* and *Topaze,* both completing at Toulon. Her dimensions are as follows: Displacement, 390 tons; I.H.P. of motors to be 600; speed, 12 knots; armament, 6 torpedo discharges, and she will carry a crew of 21 men. Like the *Emeraude,* the other three vessels when completed are to be sent to Cherbourg, and attached to the Channel Flotilla.

The submersible *Fresnet,* 398 tons, was launched at Rochfort on 16th June; she is one of the *Papin* class.—"Journal Royal United Service Institute."

FATAL GUN MISHAP ON BOARD THE GUNNERY-SHIP "COURONNE."

A serious mishap, caused by the premature explosion of the charge of a 6.4-inch Q.F. gun during the closing of the breech block, occurred on board the gunnery ship *Couronne* on the 12th ultimo, while at target practice off Salins-d'Hyères, which resulted in six men being killed, seven badly hurt, and fourteen others more or less seriously injured.

It appears that practice had been carried on from the gun —Model 93-97—during the forenoon, an average of six rounds a minute having been fired. The gun had become very hot, and at 11 A. M. practice was interrupted, to be resumed again at 1 P. M. The charge of these guns is in two parts, the cartridge itself and a copper case, containing the primer, an arrangement which has always been considered a very unsatisfactory one. Thirty-four rounds had been fired after the

resumption of the practice, and the breech block was being pushed home, when there was a tremendous burst of flame, and it was blown violently to the rear. The priming, which was being brought up to the gun for the next charge, was ignited, as well as two other charges at the rear of the guns. All the men who were on this part of the deck were struck down by the terrible blast of this hurricane of flame.

Four officers who were in rear of the gun, by some miraculous chance, only received superficial burns, while between Sub-Lieutenant Mouren, who was in charge of the firing, and Midshipman Thévenard, who was taking the time, in the small space of two paces which separated them four men lay dead. Two other officers, who were going through the gunnery course, were thrown down, but only received slight contusions. The outburst of flame set fire to the deck, the flames from the burning of which were visible to other ships lying in the Roads; but there was no panic, and the fire was fortunately soon extinguished. As the *Couronne* is an old wooden steam line-of-battle-ship, and her decks like tinder, had the fire gained a hold, the safety of the ship might well have been endangered.

It is not known what caused the explosion, as the breech block not being home and locked, the primer could not have been ignited by the blow from the striker, and the Committee of Enquiry, which has been sitting, have not yet made their report.—"La Vie Maritime," "Le Moniteur de la Flotte," and "Le Temps."

FATAL GUN MISHAP ON BOARD THE FRENCH ARMORED CRUISER "LATOUCHE-TRÉVILLE."

We regret to have to report another terrible gun accident, which has taken place on board the *Latouche-Tréville,* tender to the gunnery ship *Couronne,* by which thirteen men have lost their lives, and two have been very seriously wounded. Following so soon after the serious accident on board the *Couronne,* this has created something like consternation. The frequency of these accidents is a serious matter for the French

Navy, and most disquieting to the country; more especially because in none of them has an exact and definite reason for the disaster been forthcoming. The hypotheses that have been put forward, however well argued, are not convincing, and this cannot but lead to an uneasy feeling in the minds of all concerned.

This is the fourth serious gun accident that has taken place in the last two years, in connection with the Gunnery School at Toulon, the total casualties in which amount up to the large figure of 28 killed and 42 wounded = 70. The dates and particulars of these accidents are:

20th April, 1906, on board the *Couronne,* 3 killed, 15 wounded.
2d August, 1907, on board the *Couronne,* 3 killed, 6 wounded.
12th August, 1908, on board the *Couronne,* 9 killed, 19 wounded.
22d September, 1908, on board the *Latouche-Tréville,* 13 killed, 2 wounded.

The following account of this last accident, by an officer on board the *Latouche-Tréville,* who was an eye-witness, is given in the "Temps":

"On Tuesday, 22d September, *tirs d'honneur* were being carried out from the *Latouche-Tréville* off Toulon, for the purpose of selecting the best shots from the men under instruction to receive certificates of captains of guns. The guns used were three 14-cm. (5.4-inch) and one of 19-cm. (7.6-inch) in the after turret, and it was in this latter that the explosion took place. The ship had been steaming along a firing base, and had arrived at the end of the run, and was turning 16 points to go back again, and bring the starboard guns into action. The 'Cease fire' was sounded, and as there would be a period of about three minutes before recommencing, advantage was taken of this delay to change the gun's crew; the gun, which was loaded, being left, in accordance with the instructions, with the breech unlocked. The officer in charge of the first gun's crew warned his relief that the gun was loaded, and after this no one can say exactly what happened;

but hardly had the new crew entered the turret—not yet quite evacuated by the old crew—when an appalling explosion took place, blowing the breech block of the gun through the door of the turret, and lifting off the roof shield, 95-mm. (3.6-inch) thick, which fell on the deck, killing one man, and then bounded overboard. A jet of flame also descended the ammunition hoist to the magazine, luckily without exploding the latter. The inside of the turret, in which every man was killed, presented a horrible sight. The marvellous escape of the two officers is due to the fact that they had just before moved out of the turret to give room for the new crew to pass in.

"It was at first thought that on account of the force of the explosion more than one charge must have ignited, but this was not the case, the other cartridges being found intact.

"One theory is that the new crew, on entering the turret, opened the breech, and that the draft of air into the gun caused gas left in the chamber by previous shots to ignite and fired the charge, while the breech block, not being closed, was naturally blown out. M. Thomson, Minister of Marine, on receipt of the intelligence, at once proceeded to Toulon, and has been most unceasing in his attentions in visiting the wounded at the Saint-Mandrier Hospital, who he has decorated with the military medal. One of these two, unfortunately, did not live long to wear this distinction, and has since succumbed to his injuries, bringing the number of deaths up to 14."

The breech block, which was blown into the sea by the explosion, has since been recovered by the divers from a depth of 22 meters (72 feet), the percussion tube was found in place, and showed that it had been fired. This discovery would seem to put out of the question the theory of the explosion having been caused by a return flame, and the disaster would now appear to be due to neglect on the part of one of the gun's crew to remove the tube, according to the regulations, before opening the breech, and the tube was probably fired by tension of the tube lanyard (which may have caught in some way), caused by the withdrawing of the breech block.

The powder, which had been used up to the 47th round, came from the stock provided in 1899; but that in the gun at the time of the explosion was 1904-1906. A committee of enquiry is sitting, but the conclusions at which they have arrived have not yet been made known; one hypothesis is that the explosion was caused by some deleterious gases which had remained in the gun. Captain Darrieus, the commander of the ship, declares that he cannot accuse any of the gunners of carelessness, as, as far as was known, all the regulations laid down for firing had been most carefully carried out.—"Le Temps" and "La Vie Maritime."

THE FRENCH NAVAL SITUATION.

By M. ROUSSEAU.

The principle on which the concentration of naval forces depends conflicts with that of the dispersal of squadrons in distant seas, which had prevailed up to 1904, and has ended naturally in the creation of a new class of ship equal to the world-wide rôle required of the modern vessel.

Generally speaking, naval officers look only at their ships from the fighting point of view, the advantages of different plans of armament, and the improvements to be introduced in these respects, a few only have considered the larger question as it affects their ship, and though admittedly she must be a fighting battleship, she must also possess all the attributes for arriving at the place of action at the desired moment, and in the best condition.

The concentration of the fleet in English waters, entailed, if not the complete abolition of the *points d'appui* in distant stations, at least a great reduction in their numbers, and in the importance of those still remaining, and the distance between these thus becoming greater, the necessity arose for increasing the speed and enlarging the radius of action of the ships, hence the introduction of the *Dreadnought* type of battleship with a nominal displacement of 17,000 tons, but a real displacement

of more than 19,000 tons, on account of the supplementary supply of fuel that can be carried. Large as it is, this displacement is now exceeded, our battleships of the *Danton* class are larger, and the displacement of our projected battleships is 21,000 tons. In England each new ship built is larger than her predecessor; the American battleship, whose design has been submitted to Congress, will displace 22,000 tons, and M. Laubeuf predicts the advent of vessels of 25,000 tons.

As has been said, the new ships of the *Dreadnought* era are necessitated by the ever-increasing demands of the new strategy. In Lord Cawdor's report of November, 1905, we read the Admiralty view on the importance of rapid construction: "The quicker a new vessel can be put through her trials, the easier is it to introduce improvements which experience has shown to be necessary in succeeding vessels of her class, consequently it is most desirable to finish off the first vessel of a batch as soon as possible." This makes it clear that in constructing the *Dreadnought* the British Admiralty was taking a leap in the dark, and the experiments conducted with this ship show that besides her machinery trials her rôle and efficiency, from a strategical point of view, were also fully considered, and the necessity is also affirmed of constructing new ships in series.

This necessity is greater with the ship of the new era than with her predecessors, for if we consider that they are intended to act at great distances from their base, it is obvious that the naval force of which they form a part must be absolutely homogeneous to give the best results; difficulties might be doubled, and operations might even become impossible were there too great a difference among the ships. All must have the same speed, for the slowest ship regulates the rate of progress of the fleet; they must have the same radius of action, for the distance that can be traversed is limited to the means of the ship carrying the smallest supply or consuming the largest amount of fuel; the guns must also be disposed in a like manner on all the ships, for the fire effect will be greater if a larger number of guns can be converged on the object, and the ships must be protected to the same degree, the thickness of the armor deter-

mining the fighting range at which they will be more or less invulnerable without compromising the full effect of their own guns.

The homogeneity of a naval force depend upon all of these questions and though it need not concern itself with turbine or piston engines, with B-powder or cordite, or with horizontal or vertical-tube boilers, it is evident that the necessities of modern warfare oblige us to push this matter of homogeneity as far as we can; not only are ships of the same military power demanded, but also with the same means of producing this power, for there is besides battle-homogeneity also mobilization-homogeneity.

If the predominant idea in the conception of the *Dreadnought* is that of, so to speak, producing an autonomous vessel, able to act without reference to *points d'appui* and their resources for supplies and repair, the immediate consequence of the autonomous fleet is the organization of a floating service for repairs and replenishing of stores. This floating service, now termed *train d'escadre,* is a group of auxiliary vessels able to supply the current needs of a fleet and execute all repairs due to damage in action, or at least those that can be carried out without going into dock. It is with this object that the British Admiralty has constructed the *Assistance,* the *Aquarius,* and other vessels, whose names symbolize their duties. It is clear that the *train d'escadre* will be all the more efficacious the less varied or numerous the needs to be supplied. If all the men in an army had the same sized heads, the same clothes and foot measures, the clothing of them at mobilization would be much simplified; every man cannot be made alike, but there is no reason why ships should not be similar. If all the boilers in a fleet are of the same pattern, the repair ships will only have to carry one kind of a boiler tube, and if the caliber of the guns is the same, they will have to carry but one nature of projectile; in thus unifying the different elements in the ships, the supplies and material to be carried by the *train d'escadre* is much simplified, and the chances of mistake reduced to a minimum. It

may be mentioned that England has put the same nature of boilers in her three latest *Dreadnoughts*, not because of the superiority of this type, but because the *Dreadnought* herself carries them.

Some people affirm that the adoption of a single caliber of heavy gun is the result of the lessons of the battle of Tsushima; this, however, is not borne out by the fact that both the belligerents, Russians and Japanese, have armed their most recent ships with different descriptions of guns, and that they have not discarded guns of a medium caliber. The unification of caliber is necessitated more by questions of mobilization than by battle conditions.

Moreover, the *Dreadnought* was designed long before the battle of Tsushima, preceding even the commencement of the Russo-Japanese War. In the August, 1903, number of the "Navy League Journal," a new type, an improved *King Edward* of 18,000 tons, was proposed. The *Dreadnought* is par excellence the type of vessel that conforms with the new distribution of the fleet, and synchronizes most with the modern formula, "concentration of power and transportability of effort."

English genius has solved the application of this formula, but will the solution be to the profit of that country? Was it wise of the British Navy, with its many coaling stations and arsenals in all quarters of the globe, to show that it is possible to do without such *points d'appui?* There can be no doubt but that it is this demonstration which is the cause of all other navies now adopting this new class of ship. The Germans have increased the displacement of their new battleships by nearly 50 per cent., namely, from 13,000 to 19,000 tons. The English have taught the Germans that the world power of a fleet may reside in itself, and need not depend on territorial possessions along the ocean highways.

Germany perceived that with the *Dreadnought* type the field of action of her fleet might be unlimited, and though previously she had no necessity for ships of large tonnage, she has now

modified her naval program, and is constructing a number of these monster vessels.

It need hardly be said that the displacement of armored cruisers has increased in the same proportion as the battleships, and there is now little difference between the tonnage of the two classes. Properly speaking, the armored cruiser no longer exists—there is "the line" of battleship and the cruising battleship, the former is slower, but both have powerful armaments, and their armored protection is nearly the same. The latest English battleship will carry ten 305-mm. (12-inch) guns and twenty 101-mm. (4-inch) guns, the latest armored cruisers carry eight 305-mm. (12-inch) and sixteen 101-mm. (4-inch) guns, but the former have a speed of 21 and the latter of 25 knots. The principle of homogeneity has made it necessary to place identical guns on board new ships of different classes, the difference between the two types is one only of the number of different fighting elements.

To resume, it may be said that the characteristics of the modern navy—of a squadron of *Dreadnoughts*—are augmentation of displacement to increase speed and radius of action, and reduction in the number of fighting elements to simplify the replenishing of stores and fuel, and the carrying out of repairs. The motto of the new navy is: "Strength with simplicity.

The evolution of the *Dreadnought* type of battleship still goes on, each Navy endeavoring to produce something better. It is the combination of different qualities which conduce to the superiority of this class of ship. If she be considered simply as a fighting unit, this superiority is not so evident, for it is easy to conceive a vessel of less tonnage able to throw a greater weight of projectiles; but in such a case it would be necessary to sacrifice speed and radius of action, just as in the new cruiser battleship it has become necessary to reduce the protection and the size of the guns to obtain a speed of 25 knots.

If we admit this, it may be asked: Why have all nations

without hesitation adopted these very large displacements? Their adhesion to the principle of the giant battleship shows in the clearest manner that no Admiralty has confidence in a purely defensive navy. The attack on Port Arthur convinced everyone that rapidity of movement and quickness of action is the chief factor in success; and the *Dreadnought* is essentially offensive on account of her speed, and because she is autonomous. The tests through which she has been put after her first trials have amply affirmed this quality. She made a non-stop passage from Gibraltar to the West Indies, and on her arrival on the American side still had enough fuel in her bunkers to allow of her steaming 1,000 miles farther, notwithstanding that her speed had much exceeded the economical limit.

The example set by England has been followed by practically every nation, and now only *Dreadnoughts* are being constructed. In England the situation is as follows: The *Dreadnought,* completed more than a year ago, flies the flag of Vice Admiral Bridgeman, Commander of the Home Fleet; three other battleships (*Bellerophon, Superb* and *Temeraire*) of 18,000 tons were launched in 1907, and will be ready at the end of the current year; three more (*St. Vincent, Collingwood* and *Vanguard*) have just been laid down, and have a displacement of 19,250 tons, and will be completed at the end of 1909 or commencement of 1910; finally one other battleship is to be commenced in the financial year 1908-1909 and finished two years later. Of cruiser battleships, three (*Inflexible, Invincible* and *Indomitable*) are afloat, and will shortly be completed; and another of this class of the same displacement—17,250 tons—will be commenced during the present financial year.

Thus, at the end of 1908 England will possess eleven armored vessels of the *Dreadnought* era, either in commission or completing. This number does not seem so important when we remember that these eleven ships represent a four years' program of new construction, and if we recall that quite re-

cently Mr. Asquith, in the House of Commons, and Lord Tweedmouth, in the House of Lords, said that the rule of the two-Power standard would continue to be the guide of the Admiralty. We must nevertheless admit that, thanks to the advantage gained by being before other Powers, the British Navy is certainly superior at present to the combination of any other two; but if the new type of vessel has considerably lessened the value of preceding types, it is to be feared that in the near future a combination of two fleets may arise superior to that of England.

But, besides the two-Power rule, the British Admiralty has laid down, according to Lord Cawdor's memorandum, that the "demands of strategy necessitate the production of four large ships per year, and unless unforeseen contingencies arise, this number should not be exceeded. The period of construction of a battleship is two years, and as four ships will be laid down each year, in any single year there will be eight vessels of this class under construction, either in the dockyards or private yards."

By 1905 it had become difficult to distinguish between the battleship and the armored cruiser—both were classed under the general description of large armored vessel. Speaking of the intention to construct four battleships per year, Lord Cawdor laid this down as the future Admiralty program, and as, according to the English estimate, the life of a battleship may be put at 25 years, it follows that the British Admiralty aim at having an effective force of 100 battleships. This may also be inferred from Appendix VII, of the Naval Estimates, which allows for an annual depreciation of 40 per cent. per ship, this being also the basis of calculation for the estimated sum necessary for their replacement. (A paper distributed to the British Parliament in July gives the effective number of battleships in the fleet as 65, of which 5 are under construction, and the number of armored cruisers as 38, of which 8 are under construction.) Besides the two-Power standard the Admiralty has, therefore, another guide to work by; but it

must be stated, notwithstanding, that the "Navy League Journal" for March shows, as regards the Cawdor program, that there has since been a falling off of 25 per cent., and that in four years the number of ships laid down will be only 12 instead of 16 required.

If building activity in the British Navy appears to have slackened, this is not the case in the German Navy, whose program, which dates from 1898, is being continually modified in an increasing sense. The latest change—and, perhaps, the most important—is the one which has received least attention. The life of a battleship, which had been fixed at 25 years, has been shortened to 20 years, which means that Germany to replace her worn-out battleships will construct five new ships instead of four. If England is losing 25 per cent. per year on her program, Germany, on the contrary, is gaining that amount, and in 1908, 1909 and 1910 she will lay down four *Dreadnoughts* every year.

The adoption of these large ships has caused a certain amount of perturbation in the German Navy, and the regular sequence of her building program has suffered in consequence; but the time lost has now been pulled up, and at the end of 1908 Germany will have 9 of these giant ships building or afloat, and one year later she will have 13, which means that if England does not make a further effort she will possess no advantage at the end of 1909 over her competitor.

The following are the details as regards the German *Dreadnoughts:* Two first-class battleships of 17,710 tons were commenced in August, 1907, the first of which, the *Nassau,* has just been launched. Two of 19,000 tons and one cruiser of 18,900 tons were commenced in November, 1907, and during the current year three battleships of 19,000 tons and a cruiser of 18,900 tons will be commenced. The period of construction of each of these vessels is fixed at eighteen months.

The situation in France is quite simple. Six battleships of 18,350 tons were laid down in the end of 1906; they will be completed in 1910 or the commencement of 1911; no others

are to be commenced this year, but it is understood that six new battleships will be commenced in 1909 and 1910.

The American Navy has only two battleships of 20,000 tons actually building—the *New York* and *Delaware*. What further vessels will be laid down depends on the vote of Congress. The Government proposed to commence four battleships of 22,000 to 25,000 tons, but it would appear that Congress is not disposed to vote for more than two.

The building program of Japan may be compared to that of England. In the first quarter of 1905—that is to say, during the war—two battleships, the *Satsuma* (19,250 tons) and *Aki* (19,780), were laid down, and are both now launched. Towards the end of 1907 plans were drawn for two more battleships of 22,000 tons and one cruiser of 18,650 tons, and it is proposed to lay down one battleship of 22,000 tons and two cruisers of 18,650 tons this year.

There remains Russia, but in the present state of politics in that country it is not possible to say accurately what additions will be made to her fleet.

To resume, at the end of 1908 there will be built the following battleships of the *Dreadnought* era:

	England.	Germany.	United States.	France.	Japan.	Total.
Battleships....	8	7	4	6	5	30
Cruisers....	4	2	0	0	3	9
	12	9	4	6	8	39

—a total of 39 vessels, of which 20—or more than half—are possessed by England and Japan, whose alliance binds them to act together in case of a combination of the other Powers. On the other hand, England by herself would be outnumbered by any combination except that of France with the United States, though as regards the latter the number of her large battleships is not yet definitely fixed.

I have already said that Navies can best be compared by the number and fighting value of battleships possessed, as a

maritime war must be decided by great naval battles; and the only vessel to act in the fighting line is the first-class battleship. But though the battleship is the fighting ship *par excellence,* it does not follow that there is no need for auxiliary vessels. Admiral Fournier wished for a fleet composed only of armored cruisers, but fit to do anything; fight, scout, protect or destroy commerce; but it was pointed out at the time that an armored cruiser can not be expected to stand up to a battleship, and that if used as a scout the cruiser locked up too large a crew and burnt too much fuel; while, as regards commerce protection, so large a number would be required that the price of protection might exceed the value of commerce to be protected. Admiral Fournier did not come out of the region of theory, and France has continued to build vessels of different types, about which it is necessary to say something.

If all are in agreement as to the points of a good battleship, there is not the same unanimity of opinion regarding the subsidiary vessels of a fleet. Scouts are allowed to be necessary, but what kind of scout, and in what proportion? In France we are not building any scouts, and the intention is to use destroyers of 330 tons for the purpose; but in anything like bad weather this would lead to the battleships scouting for the destroyers. In England they seem to have arrived at some conclusion, and in 1903, 1904 and 1905 a class of scouts of 2,800 tons to 3,000 tons were built. It was intended to regularly attach them to the different fleets, but they still remain at the different naval ports, apparently not approved of even before they have had a fair trial. Last year a protected cruiser of 3,300 tons was laid down, and she is to have the same speed as the scouts, and this year five protected cruisers of 4,000 tons to 5,000 tons are being commenced. One vessel also, of 1,800 tons and 30 knots speed, is being built, designated, according to the Estimates, a torpedo vessel. For what purpose is she intended? Her utility is not clear. What, however, is certain is that she will be more or less of a luxury, and that any large number of this class could not be built.

The United States have also built scouts of 4,000 tons dis-

placement and 24 knots speed, which are now going through their trials. In Japan the same hesitation reigns as in England. In 1907 they launched a cruiser of 4,000 tons and 25 knots; one of 1,250 tons and 22 knots; and one of 1,350 tons and 25 knots. I am not in their secrets, but this appears rather unsystematic. Germany alone is methodically pursuing the construction of small cruisers, and has as many of them as battleships. No one knows for what purpose, but it is evident that if the German Admiralty builds so many they have their own reasons. They commenced with 2,645 tons displacement and 20 knots speed, and have raised this to 3,800 tons and 25 knots speed. The new English cruisers would appear to be a reply to the German ones.

The search for the best type of fighting ship leads inevitably to an increase of tonnage, for up to the present all progress tends in the direction of increased weight of engines. It may also be noted as peculiar that the Peace Conference has proved to be a fresh starting point for increased activity in war-ship building and further development in the arms with which they are provided.—"Le Temps–Journal Royal Service Inst."

ENGINEER OFFICERS IN THE GERMAN NAVY.

An Imperial Order has been issued giving engineer officers in the Navy the same rank and precedence as officers of the executive branch, and to mark the change in their position these officers are for the future to wear the same swords as those of the last named.

German public opinion has recently shown some concern at the number of mishaps to ships of the fleet (the grounding of the *Scharnhorst*, the *Hessen*, *Kaiser Wilhelm der Grosse*, etc.), which have come to light, and certain journals have gone so far as to ask whether Prince Henry is not too often absorbed by the exigencies of his high position to be able to devote himself as much as he should to his duties as Commander-in-Chief of the High-Sea Fleet.

Some surprise has been expressed at the recent apparent supersession of Vice Admiral Wodrig in the appointment of Director of Dockyards at the Ministry of Marine, especially in view of the fact that he seemed peculiarly well fitted for the post, as he has previously for some years been superintendent of the dockyard at Wilhelmshaven. He has been succeeded by Vice-Admiral Breusing, who was his successor at Wilhelmshaven. The Dockyard Department at the Ministry of Marine is responsible, among other duties, for the armament, equipment and maintenance of the fleet. The Department is divided into nine sections:

a Administration of the dockyards, under a captain.
b Service of automobile torpedoes, under a commander.
c Service of mines and booms, under a captain.
d Personnel of the dockyards, under a captain.
e Armament and fitting out of ships, under a captain.
f Repairs of ships, under an engineer of naval construction.
g Repairs of machinery, under an engineer of naval construction.
h Hydraulic works, under an engineer.
i Torpedo-boats (new construction), under a civil official.

—"Journal Royal United Service Inst."

STEAM TRIALS.

The new first-class battleship *Schlesien* has been going through her trials successfully. During a 24-hours' run with the engines developing 3,574 I.H.P., the mean speed was 12.2 knots, with a coal consumption of 886 gr. ($1\frac{15}{16}$ pounds) per I.H.P. per hour. During a three-hours' full-speed trial the engines developed 20,507 I.H.P., making 121.2 revolutions, and giving a speed of 19.53 knots.

A noticeable fact in connection with the speed trials of German battleships has been the steadily increasing rate of speed obtained. The four vessels of the *Brandenburg* class, with a displacement of 10,300 tons, which were laid down in the year

1890, had a speed of 16 knots. They were followed by the five ships of the *Kaiser* class, of 11,130 tons displacement, laid down between the years 1896-98, in which the speed was increased to 17.5 knots. In 1899-1900 came another group of five ships, the *Wittelsbachs,* the displacement of which was not much greater than the *Kaisers,* in which the speed was raised to 18 knots. In 1901-02 followed the group of five *Braunschweigs,* in which the displacement went up to 13,200 tons, with a speed of between 18.5 and 18.7 knots. Then in 1903-05 came the five ships of the *Deutschland* class, the last ship of which, the *Schleswig-Holstein,* has recently completed her trials. As originally designed the speed of the *Braunschweig* and *Deutschland* classes was also fixed at 18 knots; but, as we have stated, all five of the first-named type exceeded this speed by a good half knot, and the *Deutschland* also made 18.5 knots on her trials. In response, however, to pressure from the naval authorities the makers of the engines and boilers of the four remaining ships have succeeded in still further increasing the speed, the *Hannover, Schlesien* and *Pommern* having all made slightly over 19 knots, while the last of the group, the *Schleswig-Holstein,* in her full-speed trial over the measured mile in deep water, averaged the high speed of 19.5 knots. As the designed speed of the first four of the new German *Dreadnoughts* is only 19 knots, for fleet purposes the *Deutschlands* can be well combined with them to form one squadron if necessary.—"Jour. Royal United Service Inst."

NEW GERMAN SHIPS.

The new first-class battleship Ersatz *Sachsen* was launched on the 1st of July from the Weser yard at Bremen, and received the name of *Westphalen;* she is the second of the German *Dreadnoughts* to take the water. According to the "Hambourger Nachrichten" her dimensions are as follows: Length, 472 feet; beam, 83 feet; draught, 26 feet 4 inches, with a displacement of 18,000 tons. The engines are to develop 24,-

000 I.H.P., giving a speed of 19 knots, and she will have a radius of action of 5,500 miles at 10 knots. Protection will be afforded by a 12-inch belt, tapering to 4 inches at the extremities, with 11-inch armor for turrets and casemates, and 12-inch for the conning tower. The armament is to consist of twelve 50-caliber 11-inch guns and twelve 6-inch guns, with six submerged torpedo tubes.

Of the three new battleships of this year's program, the Ersatz *Oldenburg* is to be built at the Imperial dockyard, Wilhelmshaven, the Ersatz *Beowulf* at the Weser yard, Bremen, the Ersatz *Siegfried* at the Howaldts yard, Kiel, the large armored cruiser *"G"* at the yard of Blohm & Voss, of Hamburg, a firm which has already built the armored cruisers *Friedrich Karl, Yorck* and *Scharnhorst,* and has under construction at the present time the new armored cruiser *"F,"* of last year's program. The small cruiser Ersatz *Sperber,* at the Imperial Dockyard, Kiel, and the small cruiser Ersatz *Schwalbe,* at the Germania yard, Kiel. Of the twelve destroyers, three are to be built at the Vulcan yard, four at the Schichau-Elbing yard, and five at the Germania yard, Kiel. They are all to be of 616 tons and to be fitted with turbine engines.

A delay, due presumably to the labor troubles, has arisen in the launching of the Ersatz *Württemberg,* building in the Vulcan yard, Stettin, which was to have taken place on the 22d ultimo, and no intimation has yet been given as to the date when she now may be expected to leave the slip; she will be the third of the new 18,000-ton battleships to take the water. Although the contracts for all the new armored ships of this year's program have been given out, it does not appear that an actual commencement has yet been made with any of them, and it is stated that delay has arisen from the plans not having yet been finally settled, owing to the authorities not having come to a decision on the vexed question of the armament. It is stated that Krupp has been experimenting for some time with a view of the construction of 12-inch or even 13.5-inch guns, but it seems certain that the great bulk of naval expert

gunnery opinion is against the mounting of any heavier ordnance in the new ships than the 11-inch gun, and even that gun is looked upon by many officers as needlessly heavy.—"Revue Maritime, Marine Rundschau," and "Neue Preussiche Kreuz Zeitung."

THE PERSONNEL OF THE GERMAN FLEET.

The Officers' Corps.—The following are the numbers of the officers of different ranks on the Active List of the Fleet: 4 Admirals, 7 Vice Admirals, 16 Rear Admirals, 75 Captains, 178 Frigate and Corvette Captains, 403 Captain-Lieutenants, 952 Lieutenants, 398 Midshipmen and 185 Naval Cadets.

There are, further, 1 retired Rear Admiral, 10 retired Captains, 22 retired Frigate and Corvette Captains, and 6 retired Captain-Lieutenants employed on special duties, while 49 Captain-Lieutenants and 87 Lieutenants are employed in ordnance and torpedo duties in the various dockyards and coast stations.

The staff of the Marine battalions is as follows: 1 Colonel (Inspector of Marine Infantry, with the rank of Regimental Commander), 2 Battalion Commanders, 13 Captains, 14 First Lieutenants, and 22 Lieutenants. The Marine Field Artillery has 4 Captains, 1 First Lieutenant, and 6 Lieutenants, and the Engineer and Pioneer detachment 3 Majors, 1 Captain, and 1 First Lieutenant.

The Engineering Department consists of 10 Chief Engineers and Senior Staff Engineers, 57 Staff Engineers, 101 Senior Engineers, and 162 Engineers, being an increase of 35 over the number of last year.

The Medical Director-General consists of 1 Medical Director-General (with the rank of Rear Admiral), 4 Inspectors-General, 54 Fleet Surgeons, 85 Staff Surgeons, 51 Surgeons and 52 Assistant Surgeons, an increase of 13 over last year.

In the Accountant Department are 37 Staff Paymasters and 166 Senior Paymasters and Paymasters.

Seamen, Stokers, etc.—The Seamen's Divisions number 140

Chief Warrant Officers, 209 Warrant Officers, and 18,557 Petty Officers and Seamen, with 96 Boys' Instructors and 1,554 Boys, a total of 20,556, showing an increase of 18 Chief Warrant Officers, 10 Warrant Officers, 1,331 Petty Officers and Seamen, and 150 Boys.

The Dockyard Divisions number 347 Chief Warrant Officers, 694 Warrant Officers, and 13,249 Petty Officers and men, of whom 930 Chief and Warrant Officers and 10,849 Petty Officers and men form the engine-room personnel of the Fleet, which shows an increase of 48 Chief and Warrant Officers, and 714 Petty Officers and men over last year, with a total increase in the divisions of 53 Chief and Warrant Officers, and 821 Petty Officers and men.

The Torpedo Divisions number 106 Chief Warrant Officers, 213 Warrant Officers, and 5,796 Petty Officers and men, of whom 60 Chief and Warrant Officers, and 2,617 Petty Officers and seamen are of the seamen class, while 259 Chief and Warrant Officers, and 3,179 Petty Officers and men are of the engineering branch. There is an increase in the divisions of 17 Chief and Warrant Officers and 362 Petty Officers and men of the engineering branch and of 4 Chief and Warrant Officers and 217 Petty Officers and men of the seamen branch, a total increase in both branches of 21 Chief and Warrant Officers, and 579 Petty Officers and men.

The Seamen Artillery Division and Mining Detachment numbers 25 Chief Warrant Officers, 49 Warrant Officers, and 3,373 Petty Officers and men, of whom 2 Chief Warrant Officers, 23 Warrant Officers, and 677 Petty Officers and men belong to the Mines Division. There is an increase of 1 Chief Warrant Officer, 4 Warrant Officers, and 177 Petty Officers and men over last year, of which increase 1 Chief Warrant Officer, 2 Warrant Officers, and 64 Petty Officers and men are in the staff of the mine detachment.

The Marine Infantry numbers 210 non-commissioned officers and 1,153 men, an increase of 19 non-commissioned officers and 115 men.

The Sick-Bay Staff consists of 506 Petty Officers and men of various grades, being an increase of 34 over last year; and there are 346 ships' stewards, writers, and assistants.

The sum total of all ranks is 50,323, being an increase of 3,576 as compared with 1907.

Personnel.	Officers.	Doctors.	Non-commissioned officers and seamen.				Total all ranks, 1908.	Increase compared with 1907.
			Warrant officers.	Petty officers.	Seamen.	Boys.		
Naval officers	1,678	...	...	...	...	...	1,678	91
Junior executive officers	...	...	...	398	185	...	583	30
Engineer officers	330	...	...	...	...	...	330	35
Seamen, boys, dockyard and torpedo divisions	...	...	1,709	8,582	29,020	1,650	40,961	3,043
Seamen artillery	...	...	74	454	2,919	...	3,447	182
Marine infantry	52	...	...	210	1,153	...	1,415	136
Personnel of the clothing department	...	...	...	27	150	...	177	48
Medical department	...	247	...	214	292	...	753	47
Artillery administration	83	...	109	63	...	...	255	14
Torpedo personnel (technical and adm'strative)	53	...	119	49	...	...	221	12
Mining personnel (technical and adm'strative)	25	...	40	64	...	...	129	17
Accountant department	...	...	83	214	49	...	346	17
Surveying department	...	...	28	...	...	...	28	...
Total	2,221	247	2,162	10,275	33,768	1,650	50,323	3,576
	2,468		47,855					

—"Etat für die Verwaltung der Kaiserlichen Marine auf das Rechnungsjahr," 1908.

RECENT ADVANCES IN STEAM TURBINES.

The progress of the steam turbine is to be seen in all directions, and one thing which is especially remarkable is the rapid increase in size. Eight years ago the largest one made, which was considered an immense machine at the time, was for only 1,000 kw., and now there are large numbers ranging from 5,000 to 8,000 kw. running and under construction.

Steam turbines of large size may be roughly divided into two classes, comprising, firstly, the Parsons turbine, in which there

is both action and reaction, and the expansion takes place equally in the moving and fixed blades; secondly, those in which the whole of the expansion takes place in the fixed blades, the velocity of the steam being taken up without expansion by the moving blades. This latter class can then be subdivided into those in which at each stage there is only a single row of moving blades as in the Rateau and Zoelly turbines, or one in which there are several rows of moving and fixed blades in each stage, which take up the velocity without any additional expansion, as in the Curtis. There are again various combinations, consisting of mixtures of one or more classes, but none of these have, as yet, been manufactured to any large extent. The oldest type, and one which is more in use than any other, is the Parsons, but in America the Curtis has been manufactured in large numbers, and on the Continent the Zoelly, Rateau, and A.E.G., although both in America and on the Continent the Parsons has taken a leading position.

The Turbo Dynamo.—Hand in hand with the development of the steam turbine has gone the development of the various machinery to be driven by it, and in this direction electrical machinery has been prominent. For many years continuous-current turbo dynamos were looked at askance by engineers on account of commutation troubles, for it is easy to see that the ordinary constants applicable to slow-speed dynamos to secure sparkless commutation are far exceeded when the speed is raised to that of turbine-driven dynamos. On this account it was early seen that some sort of compensating winding to improve the commutation and compensate for the reaction of the armature was necessary. Commutating poles alone have not proved satisfactory in practice, there being nearly always considerable difficulty in securing good commutation with them, and as a consequence commutating poles combined with compensating windings—the commutating poles giving the reactance voltage necessary for commutation and the compensating winding, compensating for armature reaction—have been

adopted by many firms. But even better commutation can be secured by a compensating winding alone, in which the ampère-turns of the compensating winding exceed the ampère-turns of the armature to such an extent as to give a commutating field in the gap between the pole-pieces.

Such compensating winding is generally chiefly concentrated on the pole-pieces, and is made with from 2 to 2½ times the number of ampère-turns of the armature, in order both to compensate for leakage and to give a good commutating field; and since this method of compensating has no iron commutating pole, it has the advantage that there is no self-induction to cause time lag at sudden changes of load, and, as the field of the gap between the poles is entirely in air, it instantly responds to changes of current in the compensating winding, and thus the sparking found when there is a sudden change of load with commutating poles is avoided, and the risk of a flash-over largely reduced.

Also, since there is no iron to become saturated, the commutating field is always strictly proportional to the load, and thus the trouble due to saturation causing sparking at some loads and not at others is avoided. This advantage is specially prominent where the dynamo is required to give varying voltages and to commutate at any of them without outside adjustment of the compensating windings by diverters or otherwise.

The adoption of these devices has made it possible to make turbo dynamos of large size, and now as much as 1,500 kw. is put into a single armature, whereas before such compensating devices were adopted 500 kw. was the maximum, and even then the commutation was anything but satisfactory.

Standard Pattern.—In turbo alternators there is practically now—except for small sizes and low voltages—one standard pattern—that is, a revolving field rotating inside a stator. In the stator there is little variation in design, except in regard to the ventilating arrangements, which have to be very ample on account of the comparatively large quantity of heat to be removed from a small volume.

One point which has received great attention in recent years is the staying of the end windings of such alternators, it having been found that, owing to their great length, when a "short" took place the stresses on the winding were such as to break the insulation and cause disaster. The amount of these forces has been vastly more than was ever anticipated, and if the windings are not thoroughly stayed, such movements may be set up as to cause disaster. In the rotors there are two prominent types, the barrel and the salient pole, and much discussion has ensued as to the advantages of the one or the other. After considerable experience of both, on the whole I may say that at present I prefer the salient pole type. Ample ventilation is much easier to provide for, and improvements made in protecting and supporting the field coils of this type of rotor have resulted in a design giving great reliability with the maximum use of the space available. One improvement has been enclosing every coil in a tight sheath of sheet steel, so that any movement which may take place due to centrifugal force is between the steel sheath and the body of the rotor, and thus the insulation is protected from any rubbing which might cause it to be cut through and, consequently, break down.

Voltage regulation of alternators is also of considerable importance, as owing to the inductive load required by induction motors there is a heavy demagnetizing effect on the rotor, and consequent drop of voltage when the load rises. Several methods have been proposed for compounding alternators, most of them requiring a separate commutator or moving contacts altering the resistance of the exciter or main windings, but a method of compounding alternators has recently been brought out, which is being largely used with good results. In this apparatus the current supplied by the machine is made to act on the exciter field system in such a way as to reduce the leakage, artificially increased in the first instance, and so raise the voltage of the exciter, and increase the excitation of the alternator, so that any desired amount of compounding required can be obtained. This arrangement has been recently

described in a paper before the Institution of Electrical Engineers.

Turbo Blowers.—The other applications of the steam turbine, such as driving air compressors and pumping water, have also been largely extended during the last few years, and especially prominent in this direction has been the application of turbo blowers to blast furnace work, some having been recently installed for as much as 50,000 cubic feet of air per minute at 10 to 15 pounds pressure. In this connection it may be mentioned that a very usual size, which is for about 20,000 cubic feet, weighs about 25 tons, and that an ordinary reciprocating blower of equal capacity weighs about 450 tons or about eighteen times as much as the turbo blower.

In many parts of the country reciprocating engines are running non-condensing, and it has now been found that the exhaust steam from them is of great value. Such exhaust steam cannot be practically utilized by reciprocating engines on account of the huge size and volume of the cylinders required, but it is quite otherwise with the steam turbine, where the large volumes of the low-pressure steam are exactly what are required for the highest economy. These considerations have led to the introduction of exhaust steam turbines, taking steam at atmospheric pressure and exhausting into a condenser.

When it is remembered that there is as much power in the steam from atmospheric pressure down to 27½ inches as there is from 150 pounds down to atmospheric pressure, it is easily seen that the power of a non-condensing plant can be doubled by the addition of an exhaust steam turbine and condenser, and in cases where there is not a supply of cooling water, improvements in cooling towers have enabled them to be put up both cheaply and well.

In this connection the use of intermittent supplies of exhaust steam, such as that obtained from engines running intermittently, as in rolling mills or winding engines at collieries, has received a great impetus by the utilization of thermal accumulators, in which the intermittent supply of steam is alternately

condensed and re-evaporated, so that a constant flow is obtained for use in the exhaust steam turbine.

And yet another refinement has been introduced by the use of mixed pressure turbines, in which there is a low-pressure part sufficiently large to give full power when working with exhaust steam, and if the supply of this fails, a high-pressure part is brought automatically into action, using steam direct from the boilers, and thus there is economical running, whether the reciprocating engines supplying the exhaust steam are working or not.

The Question of Vacuum.—In all turbines the question of vacuum is a very important one, and various improvements have been made in condensers to enable higher vacua to be obtained. The importance of this will be seen when it is remembered that in the average steam turbine, 1 inch of vacuum is equivalent to from 4 to 5 per cent. of steam consumption, or, in other words, it may be taken that for every 3° F. by which the temperature due to the vacuum is reduced, a gain of steam consumption of 1 per cent. is made.

In this connection increase of circulating water is very important. A very usual amount is about thirty times, but if this is increased to 45, the gain in consumption is 4 per cent., and if increased to 65 times a further gain of 2 per cent. is made. As a rule, extra circulating water can be pumped without much difficulty, the extra power required for this being very small, but generally the temperature of the inlet to the condenser is fixed by the supply of water available.

The great desirability, then, in a condenser is to obtain the temperature due to the vacuum as close as possible to that of the water leaving the condenser, as, of course, the maximum vacuum possible is that due to the temperature of this water. In ordinary condensers, it is generally found that this difference amounts to 20 to 25° F., and among the various arrangements to reduce this may be mentioned dry-air pumps, and also the arrangement of baffles and pumps in the "contraflo" condenser. But a method which has been very satisfactory in

practice is what is called a "vacuum augmentor," which is simply a small jet of steam drawing the air and vapor from the condenser, and delivering it through a small auxiliary condenser to an ordinary air pump, so that while there may be, say, a vacuum of only 27½ inches at the air pump, 28½ inches or 29 inches may be attained in the main condenser. Such an appliance is especially valuable when, as is often the case on board ships at sea, the system has considerable air leaks. With this arrangement the difference between the temperature of the water leaving the condenser and that due to the vacuum can be reduced to about 5 or 6° F., and this when condensing up to 12 pounds of steam per hour per square foot of condenser. As will be seen, this shows an economy in the turbine of some 6 per cent. in steam consumption above an ordinary condenser, and when it is remembered that the steam jet of the augmentor uses only about 0.6 of 1 per cent., or only one-tenth of the steam consumption gained, it is easy to see that a great benefit is derived from the use of such an arrangement.

Marine Turbines.—In marine work the development of the steam turbine also is very rapid. Two years ago the great express Cunarders *Lusitania* and *Mauretania* were only in process of construction, now they have proved themselves to be the fastest liners afloat, and it is pleasing to note that the turbines of these great ships have proved most satisfactory on service. It was a great step from the 8,000 H.P. of a cross-channel steamer, which was the largest that had been made at the time these boats were designed, to the 65,000 H.P. of these express Cunarders, and reflects great credit on the courage and foresight of the Cunard Co., and also on the various contractors, designers and engineers engaged, that they have made such a great step in advance without, as many people prophesied, building another couple of *Great Easterns.* More mistakes have been made in going from a small to a large thing in engineering than in anything else, but the various pitfalls which awaited those responsible have been successfully avoided.

It is also interesting to note that the turbines proved themselves to be very economical, a consumption of 12.77 pounds per shaft horsepower having been attained as an average of the whole voyage across the Atlantic with about 150 pounds pressure at the entrance of the turbine, and a vacuum of 28.3 inches, barometer 30 inches.

At present all cross-channel steamers in hand are being fitted with steam turbines; the whole of the ships in the Admiralty program have also turbine engines, and everyone knows what a success the *Dreadnought* and the *Indomitable* are, they being respectively the fastest and most powerful battleship and cruiser afloat.

Hitherto, the link supplied between the steam consumption in a marine engine, and the horsepower developed, which is represented by the indicated horsepower, has been missing in a turbine, but the introduction of the torsion meter, which measures the horsepower passing through a shaft by the amount of torsion caused, has supplied this missing link most satisfactorily. The introduction of this has been chiefly due in this country to the enterprise of Messrs. William Denny & Bros., of Dumbarton, and on the Continent to Mr. Frahm, of Messrs. Blohm & Voss, of Hamburg, both of whom on slightly different lines have worked out torsion meters which have proved very satisfactory in practice. This has enabled the various losses between the power in the steam and the power required to propel the ship to be even better located than they are in the case of a reciprocating engine where the indicated horsepower does not take into account the friction of the engine.

Mixed Pressure Turbines.—The steam turbine, up to the present, has been almost entirely used for ships of 17 and 18 knots and above, and, in fact, it may be generally said that about 15 knots is the lowest speed of vessel at which the turbine can satisfactorily compete with the reciprocating engine as regards economy. The difficulty of the problem lies in the

fact that at low speeds the screws have to be made to revolve at small revolutions, and at the same time the horsepower required is moderate, and thus the turbines have to be very large and heavy, and, besides this, the blades are so short that the loss by leakage is excessive. These considerations have led to the combination of a reciprocating engine for the high-pressure part of the range where the volume of steam is small, and where the reciprocating engine is working exactly under the conditions for the best economy, and a turbine for the low-pressure part of the range where the volume of steam is large, and where, therefore, the turbine is working under the very best conditions, and such an arrangement gives advantages over either the turbine, or the reciprocating engine for moderate speeds, and, in fact, it is anticipated that an extra economy of about 15 per cent. can be attained in this way. The advantages of such an arrangement were first pointed out by Mr. Parsons in 1894, but has only recently been put into practice. Many various arrangements and combinations are possible, but that which appears to be most generally favored is to have twin reciprocating engines each driving their own screws exhausting into a single turbine driving a center shaft. The reciprocating engines exhaust at about atmospheric pressure, and the turbine used the expansion from that pressure down to the vacuum of the condenser, which may be 28 inches or 28½ inches. For maneuvering or going astern the reciprocating engines are used.

At present two large Atlantic liners are being built with the above arrangement for the Atlantic service, but it may be pointed out that the destroyer *Velox*, made in 1903 by the Parsons Marine Steam Turbine Co., Ltd., for the British Admiralty, was the first ship fitted with such a combination.

It may be mentioned that eight years ago there were only 25,000 H.P. of marine turbines afloat; two years ago there were 800,000 H.P., and now there are over 1¾ millions completed and under construction.—"Page's Weekly."

THE TACTICAL VALUE OF TORPEDO CRAFT.

The United States Navy has under construction four torpedo-boat destroyers of 902 tons full-load displacement, and Congress at its last session provided for ten more vessels of this general type, which will probably be between 1,000 and 1,200 tons full-load displacement. We also have under construction eight submarine boats, ranging in displacement from 274 tons to 500 tons when submerged; and Congress at its last session authorized the building of eight more submarines, at a total outlay of not more than $3,500,000. These boats will probably have displacements of not less than 400 tons when fully submerged. As can be seen, the "destroyers" and the submarines represent a very material increase to our torpedo craft, and the question is: In the light of experiments and maneuvers abroad, which type, the surface or the underwater boat, is likely to give us the better defensive return for the money expended?

Apart from the unquestionable offensive powers of the torpedo, *per se,* modern developments in the form of turbine propulsion, superheaters, and more accurate gyroscopic gears have added very materially to the range and the directness of travel. As a result, both the 18-inch and the 21-inch torpedoes have much longer effective ranges; the 18-inch being able to run 1,800 yards at a speed of 35 knots, while the 21-inch torpedo is able to cover a distance of 4,000 yards at a speed of from 26 to 27 knots. Searchlights as now installed upon modern naval vessels cannot be safely counted upon to pick up a low-lying torpedo craft at a distance of much over 1,500 yards, and it is therefore plain that the modern torpedo outranges the reach of the searchlight. Surface torpedo boats and destroyers are not exclusively designed for the use of torpedoes. Each of them carries a fairly considerable armament of rapid-fire guns, and it is evident that their torpedoes are essentially instruments of opportunity, and that that opportunity can come chiefly at night, and then under conditions more or less limited.

Extensive experiments conducted abroad have proved the utter impracticability of a successful daylight attack; the torpedo vessels being theoretically destroyed by the rapid-fire guns long before getting within torpedoing range. Accordingly, night attacks have become the object of most serious study, and with some measure of success.

During some recent maneuvers in the British navy, a problem of this sort was set the division commander of a flotilla of torpedo destroyers: A squadron of cruisers and battleships was sent to sea at night, and a division of destroyers, not informed of the whereabouts of the ships, was ordered to hunt them down and to attack them by means of torpedoes with collapsible heads. The torpedo was to be considered properly fired only when it had struck the hull of a designated ship; the captain of each torpedo craft being obliged to name the vessel chosen by him for attack, and to identify his vessel before firing the torpedoes. The net result of this experiment was that the torpedo boats discovered the vessels and were able to make their attack before their presence was observed by the battleships and cruisers, but not a single torpedo struck home, and no commander was able to state which of the enemy he had endeavored to hit. In order to strike a moving target, the torpedo must be so aimed that due allowance shall be made for the enemy's speed and the direction in which he is moving. These two elements in the triangle of fire are hard enough to estimate in broad daylight, and the difficulty is accordingly magnified by darkness, while atmospheric conditions and any dimness of light will make it hard to identify even well-known vessels. The results in the foregoing maneuvers need occasion no surprise, but they do point significantly to the desirability of securing some means of getting within torpedoing distance within the ranges of daylight, when the probabilities of successful attacks give ample reason of being for torpedo vessels. It is thus seen that the surface torpedo boat is practically denied the chance of doing effective service during the daytime,

while at night, except under limited conditions, she is a menace to both friends and foe, unless by some rare chance she be able to get safely within striking distance, and then to make sure that her target is the right one. The blinding effect of the searchlight is all too well known, and with a watchful foe so guarded, the opportunities of reaching a moving enemy are few and far between, because her speed and direction of motion can only be guessed at roughly.

The submarine torpedo boat seems to be the logical solution of the problem. Of course, their problem is the same as that of the surface boat, so far as properly calculating the direction in which the torpedo shall be aimed in order to compensate for the rate and direction in which the enemy is moving; but this is capable of solution through the medium of a proper observing instrument or periscope, and, again, this is an optical task which the Italians are said to have successfully accomplished.

Undoubtedly, underwater boats of the future will be divided into two broad classes; those for harbor and coast defense in the more restricted sense of the terms and those for offshore or seagoing purposes; the mission of the latter boats being not only to keep an enemy well to sea and beyond bombarding range of their guns, but also to accompany a battle squadron at a good cruising speed, and constitute its outlying defense when those ships are anchored in an unfortified port or improvised coaling base. Upon the resumption of the squadron's cruise, the submarines will be discharged of their duty of defense, and follow along in the rear of the big ships. Such would be the principal services of the seagoing submersible of displacements ranging from 300 to 600 tons, while the boats for strictly harbor and inshore protection would be craft of 200 tons or less, capable of holding their positions submerged for a maximum period of probably twenty-four hours. The seagoing submersibles would naturally have to have speeds of fully 15 knots an hour upon the surface, and a cruising endurance at a 10-knot clip of quite a thousand miles. This is not

calling for anything extraordinary in view of what has already been accomplished.

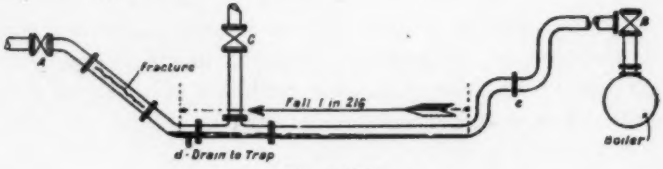
Reviewing these conditions in the light of the most recent experience abroad, may it not be justly claimed that we would do wiser by adding more to our flotilla of submarine vessels, and making of our destroyers craft of much larger displacement, so that they may properly serve the purpose of "scouts," for which a field of valuable daytime service does exist; making their torpedo equipment of secondary importance, and recognizing their chance of possible usefulness to be that of a remote opportunity?—"Scientific American."

WATER HAMMER IN STEAM PIPES.

We take the following article, on which we comment on another page, from Mr. Longridge's report for 1907 to the British Engine Boiler and Electrical Insurance Company, Limited:

Every year some lives are lost by the fracture of pipes or valve casings by water hammer. In 1907 the loss was heavier than usual. Six men were killed, three of them by one explosion. In nearly all the cases recorded since the passing of the Boiler Explosion Act in 1882 the water hammer might have been prevented if those who set it in motion—and in many instances suffered from its effects—had understood the probable consequences of their acts. It therefore seems worth while to call special attention to each of the twelve cases recorded in the Abstracts of Board of Trade Reports by describing the conditions existing at the time the water hammer occurred, and the specific act which caused it, in the hope that those who have to design steam mains, or to operate the valves and drains in connection with them, may avoid the pitfalls which these reports disclose. The sketches used for illustration are not copies of the drawings in the reports, but merely diagrams showing the particular features of the pipe arrangement which were contributory to the occurrence of the water hammer.

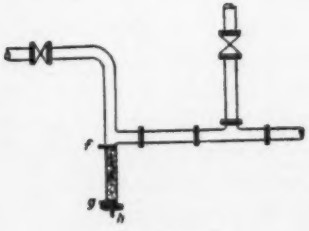
No. 1669.—Initial conditions: Pipes 250 feet long, newly erected and uncovered. Drain *d* blocked by cement jointing material and rust. Stop valve A to other boiler and boiler junction valve B shut down to re-make joint at *e*, valve C left open. Water accumulated in pipe before stoppage, cooled during stoppage.



No. 1669.

Act which caused fracture.—Opening valve B.

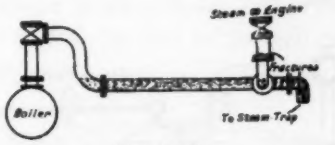
The mistake here was in relying on a steam trap for draining a new pipe. A large drain cock, without a waste pipe, should have been fitted close to the pipe. The arrangement of the pipe was bad; it should have been made as shown, with a well pipe provided with a small try cock, or some kind of float tell-tale, and a large drain cock, to be subsequently connected to a steam trap. The try cocks or float would have enabled the engineer to ascertain if the water were below the horizontal



No. 1669.

length of pipe before he opened the drain cock or the junction valve B. Try cocks, if used, must be very small, and opened for a very short time, otherwise the discharge from them may

be sufficient to disturb the surface of the water in the horizontal length of pipe, and thus start the water hammer they are intended to prevent. Floats will be referred to later.

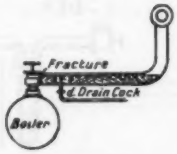


No. 1673.

No. 1673.—Initial conditions: Steam kept up on Saturday and Sunday, and boiler junction valves left open. Steam trap blocked. Horizontal length of pipe filled with condensed steam.

Act which caused fracture.—Opening valve to engine.

Here again the fault was trusting that the steam trap had kept the steam range clear, and opening the valve to the engine without shutting the junction valve. A well pipe, fitted with a small test cock or a float tell-tale, would have enabled the man to see if the pipe were clear.



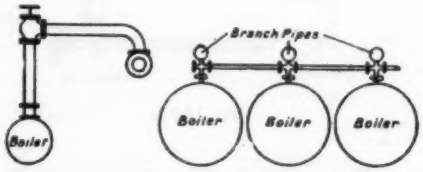
No. 1677.

No. 1677.—Initial conditions: Boiler off for cleaning, junction valve shut. Drain cock *d* left slightly open, and got blocked. Water accumulated in horizontal branch.

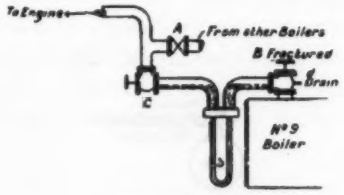
Act which caused the water hammer.—Man opened drain cock *d* full to blow out obstruction.

The fault was in opening the cock without first shutting the junction valves of all the boilers. Where there is more than one boiler the branch pipes should be fixed as below, or if this be impossible for want of head room, all the branches should be drained by large pipes without cocks or valves, leading into

a main pipe across the range of boilers, with a connection controlled by a cock to each boiler, as indicated by the diagram, so that when any boiler is stopped its branch pipe will drain into the other boilers.



No. 1678.—Initial conditions: No. 9 boiler off for three weeks, junction valve B closed, stop valve C very leaky, open at time of explosion. Drain *d* open, stop valve A, leading to other boilers, shut 15 hours before explosion. Superheater S contained water, and possibly also the 7-inch pipe up to the level of drain *d*.



No. 1678.

Act which caused water hammer.—Opening stop valve A to give steam to engine.

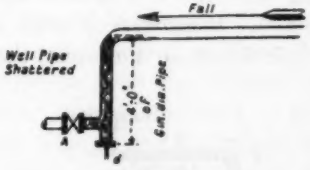
The fault was in opening the valve A before closing the valve C. The man ought to have known that unless the valves B and C were absolutely tight there would probably be water in the superheater. He ought, therefore, to have shut the valve C before opening A, and left it closed with the water in the superheater till the fire was lighted in No. 9 boiler to boil it off. The drain *d* should, of course, have been fixed at the lowest possible point of the pipe.

No. 1683.—Initial conditions: Nos. 1, 2, 3 boilers working; No. 4 boiler empty for thirty-one hours; drain *d* slightly open, sluice valve shut. Water accumulated in lower end of steam main and branch to No. 4 boiler, either through slightly opened drain cock getting blocked or through condensation in pipe exceeding discharge.

No. 1683.

Act which caused water hammer.—Opening sluice valve without shutting the stop valves in the other boilers. If the drain *d* had been cross-connected to the other boilers, as shown on the third sketch belonging to No. 1677, the steam main might have been kept free from water.

No. 1685.—Initial conditions: Steam left to condense in 90 feet of new uncovered pipe varying from 9 inches to 6 inches diameter during dinner hour; engine stop valve A shut, drain *d* shut.

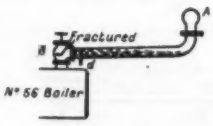


No. 1685.

Act which caused water hammer.—Opening the engine stop valve A.

The fault was in opening the engine stop valve before closing the boiler junction valve and opening the drain *d*. With the well pipe overflowing into the steam main, it would have been dangerous to open the drain *d* without first shutting the boiler junction valves. A try cock or a float tell-tale would have shown whether the well pipe was full.

No. 1700.—Initial conditions: Boiler No. 56 empty, junction valve B shut, drain *d* shut. Other boilers in connection with steam main A working. Condensed steam accumulated in branch pipe, and got cool.



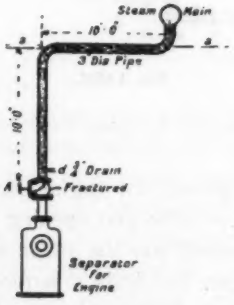
No. 1700.

Act which produced water hammer.—Opening drain *d*.

The fault was in opening the drain without shutting off steam from the main A. The drain *d* should have been cross-connected to other boilers, or, at least, to one of them, as shown in the third sketch belonging to No. 1677.

No. 1717.—Initial conditions: Stop valve A shut, drain *d* shut, 3-inch pipe full of condensed steam at low temperature.

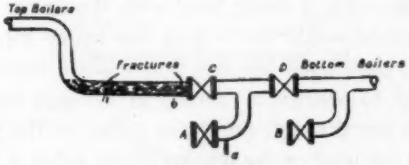
Act which caused water hammer.—Opening drain *d* two turns, giving an opening of 0.137 square inch for two minutes (?), or, if this did not lower the water level in the 3-inch pipe to *a a*, opening the stop valve A after the drain had been open two minutes (?). Whichever of these acts lowered the water level in the 3-inch pipe to *a a* caused the water hammer.



No. 1717.

The fault was in opening the drain or the valve without shutting the steam off the steam main. The drain should have been trapped and left open, but the better plan would have been to have placed the stop valve A close under the steam main.

No. 1722.—Initial conditions: Stop valve C shut, *d* open. Engine stop valve A open, drain *d* shut. Condensed steam had accumulated and cooled in pipe *a b*.

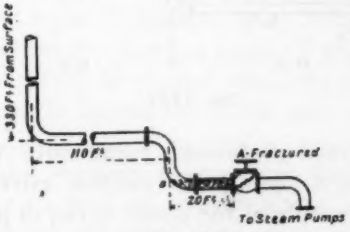


No. 1722.

Act which caused water hammer.—Closing valve D, opening drain *d* and valve C.

The fault was in opening C before closing the junction valves on the top boilers. To avoid the necessity of having to close these valves before opening the valve C, the pipe *a b* should have been fitted with a large drain leading to a steam trap, which would have kept the pipe clear so long as the trap acted. But the better plan would have been to have had a well pipe close to C, drained by a trap, and fitted with a float telltale or small test cock, or both, as above described, to enable the man in charge to ascertain whether the pipe were free from water before opening the valve C, and to warn him to shut the junction valve on the top boilers if it were not.

No. 1727.—Initial conditions: Valve A shut, lower part

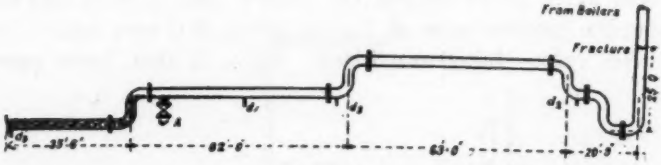


No. 1727.

of pipe filled with water, the result of half an hour's condensation in steam pipe from surface to bottom of pit.

Act which caused water hammer.—Opening valve A to pumps.

The fault was in opening A before closing the boiler junction valve. A water hammer was almost unavoidable in this case, because it was impossible to empty the pipe *a b* owing to the seat of the valve A being level with the center of the pipe. The only chance would be to shut the boiler junction valve, then open A, then open the junction valve a very small fraction of a turn to prevent a vacuum in the pipe and allow the water to run out through the drain cocks on the pump cylinders down to the level of the seating of the valve A, and then to open the junction valve a little wider, just sufficiently to cause agitation without violent motion of the water remaining in the pipe, in order to heat this water. With great care it might be possible to heat the water sufficiently to prevent water hammer, but considering the great length of steam pipe this is very doubtful. Had the valve A been a sluice valve, all the water might with care have been got rid of through the drains of the pump cylinders without accident. There should, of course, have been at least a drain at the lowest point of the pipe, which should have been open whenever A was shut; but the proper thing in such a case is a well pipe with try cocks or a float telltale.



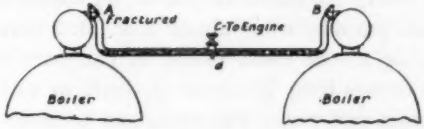
No. 1737.

No. 1737.—Initial conditions: Small valve A shut, drains d_3 shut, drain d_2 d_2 open, boiler junction valve open. Condensed steam accumulated and cooled in end of pipe.

Act which caused water hammer.—Partly opening small

valve A and drain d_5. The water hammer was not hard enough to knock off the end of the pipe, but it shook the range sufficiently to break it about 200 feet back.

Again, the fault was in attempting to drain off the water without shutting the boiler stop valve. The drain d_5 should have been trapped, or better still, there should have been a well pipe with tell-tale at the low end of the range.



No. 1738.

No. 1738.—Initial conditions: Engine standing for some hours, valves A, B, C shut, drain *d* shut. Condensing steam leaking past A and B accumulated and cooled in pipe.

Act which caused water hammer.—Opening drain *d* and easing junction valve B.

The first fault was in keeping *d* shut with leaky stop valves; the second in opening B before all the water had escaped from the pipe.

In all these cases the water hammer was caused by the disturbance of a comparatively large water surface in a horizontal or inclined pipe, in which the water was capable of moving; and wherever there is such a water surface water hammer will almost certainly be produced if that surface be disturbed by the opening of a valve or a drain.

Therefore, whenever there is any doubt about the presence of water in such a pipe it is dangerous to attempt to drain the water away without first shutting steam off the pipe. From a vertical pipe water can be drained with little risk, because the water resting on the bottom end of the pipe cannot be set in motion.

Mr. Longridge suggests an ingenious form of float tell-tale to indicate the level of water standing in a down pipe, which is well worth the attention of steam users.—"The Engineer."

MARINE BOILER EXPLOSIONS.

[From the Board of Trade Reports.]

Report No. 1,728 deals with a mishap to the boiler of the trawler *Balmoral Castle*. The vessel is engaged in trawling from Aberdeen, and on the 17th December last she proceeded to the fishing grounds off that coast. The following day the fishermen were mending their nets for shooting the trawl, the engines being stopped and the boiler steam being maintained at 140 pounds, when about 1 P. M. a crack occurred at the knuckle of the front flange of the port furnace. It measured 9 inches long by about $\frac{1}{32}$ inch in width, and the escape of steam and water was sufficient to force the attendant to retire on deck. As it was impracticable to effect any repairs, the vessel was towed by another trawler back to Aberdeen. When the defective part was being cut out it was found that the mark extended for 27 inches. The cause of the casualty was considered to be due to the rigidity of the furnace not being adapted to the stresses caused by considerable fluctuations of temperature, consequently the continued expansions and contractions gradually developed the crack.

Report No. 1,731 deals with the blowing out of a screwed plug from the bottom of the main boiler of the *Ingram* last November. The vessel left Beckton, in ballast, about 11 A. M. on the 6th of that month, bound for Tyne Dock, and about an hour later there was a sudden escape of water and steam from the bottom of the boiler, and the water level sank quicker than the donkey and auxiliary feed could make up. When the boiler had emptied itself a hole about 1½ inches in diameter was found in the bottom of the shell, but the plug could not be found. It appears that the thread was fine, and leakage had caused corrosion of the plate, the result being as stated. A through bolt with washers was fitted and the vessel completed her voyage.

Report No. 1,734 deals with a mishap to the main boiler of the *Derwent*. The vessel left Cardiff for Cowes, with a cargo of flour, about 10 P. M., on 7th January last. The boilers were leaky and steam could not be maintained, so the vessel

returned to Barry Roads; at 5 P. M. on the 9th a fresh start was made, but three hours later water commenced to run out of the port furnace. By 2·30 the following morning the leak had increased so much that the donkey had to be put on from the sea, and at 3 A. M. there was an explosion in the port combustion chamber, steam and water pouring out of the furnace mouth. The fires were drawn, and a later examination showed a hole had been formed in the bottom plate of the combustion chamber. The vessel drifted about till 10 A. M., when she was taken in tow to Barry. It was then found that the boiler was in a very defective condition; the vessel was consequently stopped for a new boiler.

Report No. 1,735 deals with a steampipe mishap on the *Dunbar* in November, 1906. The pipe was of solid-drawn copper, 4¾-inch bore, and about ¼ inch in thickness. The vessel is fitted with two single-ended boilers, with separate pipes to the engine stop-valve chest. She left Cardiff in October, 1906, for Bombay with a full cargo of coal, and arrived at Suez in November. She cleared the canal about 4 P. M. on the 2d of that month, and half an hour later there was a slight escape of steam from the starboard main steampipe near the boiler stop valve. The chief engineer found that the pipe was fractured circumferentially for a length of 10 inches near the flange. The steam pressure was immediately reduced from 170 to 90 pounds, and the vessel put back to Suez where the pipe was taken ashore, 1¾ inches in length cut off the end, the flange rebrazed on the shortened pipe and a distance piece made to make up for the shortened length. The pipe has since given no trouble. It seems that on the voyage previous to the explosion the vessel encountered bad weather when in ballast, causing considerable vibration of the engines. This had evidently severely stressed the pipe, causing its subsequent failure.

Report No. 1,736 deals with an explosion of the auxiliary steampipe leading to the steering engine on the *Ardmount*. The vessel was on a voyage from Melbourne to Antwerp, and was making for Albany for bunker coal, being about 36 hours

distant at 12·10 A. M. on 1st November last. The chief engineer, on going off watch at midnight, heard a noise of escaping steam. Some lagging was removed from the pipe in question and a small longitudinal crack was seen in the middle of the pipe. The chief and third engineers were below looking for a clamp to stop the leak, when the pipe fractured with a loud report, the opening being 24¾ inches long and the greatest width of the opening being 7⅛ inches, the shock of the explosion causing the pipe to break away from one flange. The third engineer escaped on deck, and the chief got up the tunnel, taking the Chinese greaser with him. The steam was shut off and the hand-steering gear shipped and used till the following morning, when steam was raised in the donkey boiler and that range of pipes used till Albany was reached, where a new pipe was fitted. The copper was analyzed and tested, and found to be deficient in ductility.

Report No. 1,738 deals with an explosion of a stop-valve chest on the dredger *Beaufort* last December. The vessel was thoroughly overhauled at Barrow in August, last year, and on completion proceeded to Heysham, and was there employed on tide work, working four hours and idling eight hours. Owing to the arrangement of the steam pipes, a large amount of condensed water accumulates in them when the stop valves are closed. On 11th December the vessel ceased work at 5 P. M., and just before 1 A. M. on the 12th the second engineer proceeded to get all ready for starting again. He opened a drain cock and then opened one of the boiler stop valves slightly, to assist in driving the water out of the pipes. The immediate result was the driving of the water in the pipes to the other stop valve, where it broke the top flange off the chest.

Report No. 1,741 deals with a casualty to one of the main boilers on the *Wileysike* in December last. The vessel left Troon on the 17th of that month for Genoa, with a cargo of 3,100 tons of coal. About 4·30 A. M. on the 20th, when the vessel was about 25 miles off the Scilly Islands, water was found to be flowing out of the two lower furnaces of the star-

board boiler. The stop valve was closed, the fires drawn, the safety valves eased and the blowdown cock opened. At 8 A. M. the chief and second engineers went into the center chamber and found a crack in the bottom corner of the back tube plate, extending to a rivet hole, from which the rivet had been blown out. The vessel put into Falmouth with steam from the port boiler. The cracked plate was cut out there and a riveted patch fitted. The plate had thinned locally by corrosion, and in addition the stresses due to expansion and contraction had been severe.

Report No. 1,746 deals with a mishap to the boiler of the steam fishing vessel *Rhodesia* in December last. She left Grimsby on the 13th of that month, and the following day, about 11·30 P. M., when steaming full speed, about 240 miles off Spurn Point, the lower front-end plate cracked circumferentially for a length of 18 inches at the root of the flange by which it was attached to the port furnace. This was due to the variations of temperature, causing deterioration in the quality of the metal by panting action.

Report No. 1,747 deals with the fracture of a stop-valve chest on the *Kinfauns Castle* on 23d February last, the vessel being in latitude 28° 14′ S., on a voyage from Southampton to Cape Town. The vessel left her home port, using steam from five out of her six boilers. One of these was subsequently shut off and steam raised on the one not previously in use, and it was on coupling this one to the main range that the explosion occurred, owing to water hammer.

Report No. 1,754 deals with an explosion from a feed-check valve chest on the *Suir*, one of the River Liffey steam barges. This was a very simple mishap. The stop pin in the spindle to prevent the thread being screwed out of the bridge had come out unnoticed, the result being that on opening the valve full, the thread was screwed out, and the spindle was then blown out of the cover of the chest.

Report No. 1,756 deals with a mishap to the steam tug *Clarissa*. The vessel left Cardiff on 1st April, last, towing a sailing vessel. The tow was cast off at midnight when off

Lundy Island and the tug remained in the vicinity "seeking" till the 4th, when she made for Cardiff. At 2·30 P. M., when the vessel was six miles off Ilfracombe, the driver, who was on deck, noticed a whitish color in the funnel smoke. On going below he found water running out of the starboard furnace to such an extent that he had to draw the fires. The vessel drifted into shallow water where she dropped anchor, and was subsequently towed into Ilfracombe. The cause of the trouble was a defective patch on the bottom of the combustion chamber, which was much wasted owing to leakage.

Report No. 1,757 deals with an explosion from a boiler on the *Kura* last March, whilst on a passage from South Shields to Kustendje. The vessel left Tyne dock on 5th March, in ballast, and all went well till 7·50 P. M. on the 17th, when the second engineer observed steam coming through crevices around the door in the bulkhead between the engine and boiler rooms. He partly opened the door, but was driven back by steam. As large volumes of steam were also coming up the stokehold fiddley, the attention of those on deck was drawn to the matter and they turned out the other engineers. The safety valves on both boilers were lifted and the engines kept running to work off the steam. Half an hour later the engineers were able to get into the stokehold, and one fireman was found scalded to death. The other fireman on watch was scalded on the face, but had escaped up the stokehold ladder. On examining the port boiler, a back-end nut was found missing from a tube stopper in one of the stay tubes, and it had apparently been blown off, owing to the threads getting defective. It seems that the stay tube was broken and the area of the stopper was only one-fourth of the area of the tube, hence the stress was excessive, and this, coupled with the fact that the stopper had been in the tube more than twelve months, which was an error of judgment under the circumstances, resulted in the explosion.

Report No. 1,762 deals with a mishap to the boiler of the *Tweed*, a coaster employed between Berwick and Leith. The vessel left the former port on 22d June last, about 10 A. M.,

and an hour and a half later steam and water was noticed to be coming from the starboard furnace. The fires were drawn, the steam worked off and sails set till 7·30 P. M., when the anchor was dropped; a small hole was found at the back end of the furnace, which was stopped with a bolt and washers, after which the vessel proceeded. Leakage from the adjacent seam had caused locally corrosion of the plate.—"The Steamship."

FIRING WITH COAL AND OIL FUEL IN COMBINATION.

A process of using solid and liquid fuel together is now being demonstrated at the Caledonian Engine Works, Pentonville, London, N.

We give below the records of three tests, from which it will be seen that highly satisfactory results have been obtained by the new system.

The first test was made with the experimental boiler fired by means of a furnace in the ordinary way; the second after turning over to the new system, while the third test was made for the percentage of CO_2 in the flue gases, also after turning over, but too late for a comparative test for CO_2 being made with the furnace in the ordinary condition. But the fact that smoke was emitted half the time during the first test shows that the CO_2 was very low under the ordinary firing conditions.

The boiler is worked in the open without any lagging, and the coal used in the first and second tests was of a very inferior quality. The equivalent evaporation in the first case was 6.35 pounds per pound of coal, but this was only possible with the emission of objectionable smoke half the time, whereas, with the new process the equivalent evaporation was 10.03 pounds per pound of coal + about 4 per cent. of oil, with no smoke emitted.

The third test was made first, with steam alone passing through the apparatus. The coal in this instance was ordinary dross coal of rather better quality than that used in the first and second tests. An average of 11½ per cent. CO_2 was obtained. About 4 per cent. of oil was then turned on, when

the average percentage of CO_2 increased to over 14 per cent., $14\frac{3}{4}$ per cent. being registered in one instance.

When such an advantage can be obtained immediately by merely turning a tap, it is evident that there will be a large demand for the new process, especially on board ship, in electric generating stations, dye works, paper mills, and all works where there is a liability to sudden demands for an increased supply of steam being made upon the boiler.

The essential feature of this process is that the oil is gasified in retorts which are arranged in the furnace. The oil is first injected into the retort from the front of the furnace by a jet of steam through a special nozzle, and from there it travels down the center of the furnace to the end of the fire, then along the back of the fire and returns to the front, being all the time within the heated retort. On reaching the front of the furnace in a gasified state it ignites and is blown down on the top of the coal fire, when an intensely hot flame is created in the whole of the furnace. The proportion of oil and coal can be varied at will.

The process is being introduced by Direct Gas Fuel, Limited, 17 Victoria Street, Westminster, S. W.

RECORD OF TEST WITH SOLID FUEL ONLY ON CORNISH BOILER 3 FEET 9 INCHES DIAMETER BY 12 FEET LONG, FLUE 2 FEET DIAMETER.

Situation	Caledonian Engine Works.
Date of test	Friday, 19th June, 1908.
Time of starting, 2 P. M. / Time of finishing, 6 P. M. — Duration of test, hours	4
Total water evaporated, pounds	1,670
Total coal charged, 336 pounds ash, 30 pounds net, pounds	306
Fuel oil	*Nil.*
Grate area, square feet	7
Net solid combustible burnt per square foot of grate per hour, pounds	10.92
Water evaporated per square foot of grate, per hour, pounds	59.6
pound of solid combustible, pounds	5.4
Boiler pressure, pounds	55
Temperature of feed water, degrees Fahrenheit	70
Water evaporated per pound of solid combustible from and at 212 degrees Fahrenheit, pounds	6.35
Quality and amount of smoke, dark brown	½ hour in each hour.
Natural draft of chimney, poor; inch, about	0.35

Temperature of outside air, shade, degrees Fahrenheit	70
solar, degrees Fahrenheit	109
Wind	Light N. W.
Barometric pressure	29.83
Description of coal used: Poor quality nuts and about 33 per cent. dust. Cheapest to be had in London, 10 per cent. ash, B. T. U.	11,400
Remarks: Boiler worked in open. No covering composition.	

RECORD OF TEST WITH SOLID AND LIQUID FUEL COMBINED ON CORNISH BOILER 3 FEET 9 INCHES DIAMETER BY 12 FEET LONG, FLUE 2 FEET DIAMETER.

Situation	Caledonian Engine Works.
Date of test	Friday, 10th July, 1908.
Time of starting, 2·15 P. M. / Time of finishing, 6·15 P. M. — Duration of test, hours	4
Total water evaporated, pounds	3,300
Total coal charged, 440 pounds ash, 53 pounds net, pounds	387
Oil fuel, pounds	16
Grate area, square feet	6
Net solid combustible burnt per square foot of grate per hour, pounds	16.12
Water evaporated per square foot of grate per hour, pounds	137.5
pound of solid combustible, pounds	8.52
Boiler pressure, pounds	60
Temperature of feed water, degrees Fahrenheit	70
Water evaporated per pound of combustible from and at 212 degrees Fahrenheit, pounds	10.03
Quality and amount of smoke	No smoke.
Natural draft of chimney, poor; inch, about	·35
Temperature of outside air, shade, degrees Fahrenheit	72
Wind	Light S. W.
Barometric pressure	29.83
Description of coal used: Poor quality nuts with about 30 per cent. of dust. Cheapest to be had in London, 12 per cent. ash, B.T.U.	11,400
Remarks: Boiler worked in open. No covering composition.	

PATENT FURNACE FOR BURNING COAL AND OIL TOGETHER.

Tests made 13th August, 1908, by Mr. Wakeham, of Messrs. Sanders, Rehders & Co., Ltd., with the Sarco CO_2 machine.

The following percentages of CO_2 were obtained previous to the oil being fed, but with the steam jet on. These tests were taken about every two minutes: 11½, 13, 12, 11, 11½, 12 per cent.

A number of tests were then taken with the assistance of the oil, the periods between each test being the same as before. A marked improvement was shown, the figures being

as follows: 12½, 13, 14, 14½, 14½, 13½, 13, 14¾, 14½ per cent.

The coal in this case was ordinary Derby nuts, about 13,400 B. T. U., plus about 4 per cent., oil about 19,300 B. T. U., 920 specific gravity, and 150 degrees flash point. —"The Steamship."

THORNYCROFT PARAFFIN MOTORS FOR THE ROYAL ITALIAN NAVY.

These engines, which are to be installed in two twin-screw submarine boats, are constructed in four-cylinder units, bolted together, making eight cylinders on each shaft. The dimensions of the cylinders are 12 inches diameter by 8 inches stroke.

They are totally enclosed and lubrication is forced to all bearings, those on the crankshaft, and also the bottom of the crankcase, being water-cooled.

In addition to this, the pistons and crank case generally are continuously cooled by sucking cold air, which is drawn through by an exhausting fan.

Facilities are provided for the removal and replacement of the pistons and connecting rods through the doors in front of the engine, thus rendering removal of the cylinders and access from the back of the motor unnecessary—an advantageous feature for submarine boats.

Cooling water is circulated by a separately-driven centrifugal pump, driven by either an electric motor or a small oil motor using the same fuel as the main engine. A great advantage of this method is that the motor may be cooled more rapidly after running, in case examination or adjustment become necessary. The separate drive also allows of a close regulation of the quantity of water to suit the needs of the engine, according to the nature of fuel used.

The special paraffin vaporizer is fitted with a variable exhaust by-pass, so that the temperature may be exactly graduated to the needs of the particular fuel used. This is very essential, as the oils used for fuel vary so greatly in the amount

of heat required to vaporize them, and excess of heat is as harmful as too little. With a proper regulation of heat the engine or vaporizer never requires to be cleaned, as there is no tar deposit. Trouble on this score is absolutely non-existent with these engines.

An entirely novel feature is the reversing mechanism. Instead of the usual method of using a double set of cams for running in either direction, the cam shaft is so arranged that, whichever direction the engine itself runs, the cam shaft turns in one direction only, and to provide for this a reversible bevel drive, with positive clutches, is fitted.

Starting in either direction is effected by means of compressed air, the valves controlling which are cut off immediately the engine is firing.

Low-tension magneto ignition, and distributor, are fitted in conjunction with a special form of make-and-break gear in the cylinders.

The consumption of fuel is very low, being about .7 pint of paraffin or petrol per brake horsepower per hour.

The engines are designed with ample bearing surfaces, and are in every way suitable for heavy continuous service.

The total weight per four-cylinder set is 70 cwts.

The following table of results of a three-hours' trial is of interest:

TRIAL OF F4 1 AND 2, 8-CYLINDER 12-INCH DIAMETER BY 8-INCH STROKE, REVERSING.

Fuel used, Phoebus paraffin, S. G., 0.820
Consumption, 0.66 pint per B.H.P. per hour.

Time from start,		B.H.P.	Revs.
0	hours;	324;	550
0½		328	555
1		340	590
1½		327	595
2		318	595
2½		318	600
3		324	600

Average revolutions per minute, 582.5
Average power, 325.5 B.H.P.

ENGINEER OFFICERS.

Mr. Charles de Grave Sells, Genoa, the well-known engineering writer, has contributed a very important article on Engineer Officers to the new edition of "Fighting Ships," 1908. The author says that the dearth of experienced engineer officers in the United States Navy increases, and the Chief of the Bureau of Steam Engineering returns to the matter in his annual report to the Secretary of the Navy. He calls attention to his special report on the instruction of young line officers in engineering, and states as follows:

"In this report the necessity of officers specializing in engineering is discussed, and mention made of the success which has attended the performance by officers of the line of all engineering duty on board ships in commission.

"This duty on board ships in commission is primarily the care and manipulation of machinery, for which the eminently practical education in engineering obtained at the Naval Academy is a most fitting prelude, and reports received from commanding officers bear witness to the success of this plan of having engineering duties performed by officers of the line.

"That certain officers should be given further instruction in engineering, in other words, should specialize in engineering, requires no argument, as the nature of the duties demanded of them make plain the necessity. These duties, other than those on board ship, are: Heads of departments of steam engineering at the various navy yards and stations; inspectors of machinery at private building plants; inspectors of material at the numerous manufacturing establishments engaged in work for the Government; the designing of machinery at the Bureau; and the inspection of detail designs submitted by contractors, in order to make sure that the requirements of the specifications are complied with in every particular. For these positions an officer must be thoroughly conversant with the profession of engineering, as upon his judgment depends the success of the machinery installation of our ships, as well as the economical expenditure of large sums of money.

"The designer of machinery must not only be familiar with all the elements of machine design, with current and best practice, but must have that intimate knowledge of the needs of arrangements and installations which can be obtained only by association with the finished product at sea. It is for this reason that the most successful designers of marine machinery are found among those engineers who have had sea experience, who have stood a watch in the engineer department of a vessel in commission, and who have had their existence made miserable by the faulty and academic design of an engineer who has not had experience at sea. On this account the Bureau has always opposed the separation of the designing and of the operating engineer, and it believes that the result of its policy has been attested by the success of its designs. Even where the details of the design are left with the builder, the Bureau keeps a rigid watch over them by a critical inspection of the details submitted before work is begun, this inspection not infrequently resulting in important modifications, and in some cases to absolute disapproval of certain details.

"That this work may be done, and done properly, officers with a natural bent for engineering should be encouraged to 'specialize in engineering,' and should be given the instruction necessary for them to attain that end.

"Unfortunately, the number assigned to this important work has never been large enough to meet the demands of the service, and during the past year, it was far below the number that should have been detailed. But it is upon this body of officers that the department must look for the proper performance of the important duties enumerated, and it is of the greatest importance that the Government should have among its officers a large number of specialists in engineering.

"Engineering knowledge is a necessity for the modern naval officer, and the Navy must have engineers, no matter what they are called."

Mr. Sells goes on to say that—

"A somewhat similar state of affairs seems likely to prevail in the British Navy, and it is looked upon as such a grave

menace to its engineering efficiency, that the Engineering Institutions of England and the leading technical periodicals have taken up the matter seriously, and urge something being done without delay to remedy the trouble.

"The Institutions advocate an independent corps of Royal Naval Engineers, who would be trained as engineers, and who would devote their whole lives to engineering, these officers to have control in their own department, but in no case to succeed to the command of ships. To anyone with an intimate knowledge of the matter, this arrangment is not only a reasonable one, but the only one that is certain to be successful. The decision of the authorities, however, was that there should be fusion of the deck and engineer branches, and that officers in the engineering branch should have opportunities of succeeding to command, equal to the officers of the gunnery and torpedo branches. This is a very pretty idea in theory, but in practice it will assuredly lead to a decline in the specialist efficiency of both branches, nor has this 'succeeding to command' of a vessel been asked for, nor is it looked upon as in the slightest degree desirable, by an engineer who has a love of his profession. The new systems of training seem to be based throughout on the idea that all the duties of the Navy should be more or less common, with the result that in some cases, important duties are intrusted to people who are inefficiently trained for them, and in the case of engineering duties, to those who cannot possibly be as well versed in mechanical matters as the present engineering staff. The President of the N. E. Coast Institute of Engineers, in the opening address of the current session, specially called attention to one effect of the new departure. He stated that a recent order of the Admiralty had taken the mechanical charge of the gunnery and torpedo machinery of the fleet from the professionally-trained engineer branch, and given it to the mechanically-untrained gunnery and torpedo branches, and that the new arrangements had already in a notable case produced serious inefficiency, for in one of the latest battleships it had been found impossible to work the guns or to hoist up the ammunition after the machin-

ery had been for a short time in the hands of untrained men, and accordingly the engineer staff had to be requisitioned, and work day and night to get the gun gear in working order before the vessel could do her battle practice.

"The details of the new scheme provide for the cadets being rated as midshipmen on completing their training, they will then serve for a period of three years at sea, during which period they will work with the executive officers for training in deck duties and seamanship, and with specialist officers for training and instruction in gunnery, torpedo, navigation and pilotage, and engineering, a special proviso being made that one-third of the time is to be spent with the engineer officer.

"During the time they are attached to the engine-room department, the training is to be as follows: To learn the methods and practice adopted in harbor for the care and maintenance of the machinery; to acquire the knowledge and experience which will enable them to take the duty of engineer officer of the watch; to see such repair work as is going on in any department, and take part in examination of the hull and machinery; to take advantage of such opportunities as present themselves of seeing engineering operations in the dockyards; to keep an engineering notebook with descriptions and sketches; and to make acquaintance with the accounts kept of the stores, and the engine-room register and defects list.

"After three years they will be examined for the rank of lieutenant, when amongst other qualifications they will have to present a certificate showing that they have practical knowledge of engine-room duties, and that they have satisfactorily performed the duty of engineer officer of the watch.

"The examination is to consist of the five following compulsory subjects: 1, Seamanship; 2, navigation and pilotage; 3, engineering; 4, gunnery; 5, torpedo.

"If they pass in these five they may take up at least two of the following voluntary subjects: Practical mathematics, mechanics and heat, electricity, advanced French, German, Italian, Spanish, Russian or Japanese, and naval history.

"They must then serve not less than two years as commis-

sioned officers at sea, and at the end of this service officers will be selected to specialize in the various branches: Gunnery, torpedo, navigation or engineering, and these will attend a course of two terms, approximately six months, at the Royal Naval College at Greenwich.

"The result of all this may be excellent officers with a certain amount of engineering experience, but engineers in the full sense of the term they cannot be. They may be able to get along well enough in peace time and as long as things go all right, but in time of war will come the need of instant decisions, when there is no time or opportunity to sit down and think what would be the best thing to be done, and it is then one must rely on that thorough experience, which through years of practical work has become a second nature. This experience can only be ingrained into one by beginning to be an engineer when young, and the habit is then formed and grows of 'thinking engineering,' a habit it would be difficult, if not impossible, to acquire after one's tastes and habits are formed, and when, after all, engineering is only one of five subjects equally claiming one's thoughts, and to the average naval officer the least appealing of them to his tastes.

"It is to the life-long experience of its present engineer officers that the British Navy owes its brilliant successes of recent years, turbine engines, water-tube boilers, and liquid-fuel burning, and it is intensely to be regretted that the high attainments and services of these officers are not more appreciated.

"There is another very serious side to this question; the Engineer-in-Chief of the U. S. Navy in his report especially insists on the point that the engineer officer should be better informed than his subordinates, as otherwise he is 'worse than useless.' The inevitable result of such a hybrid training for engineer officers as is now proposed, cannot but result in placing them to a large extent in the hands of the engine-room artificers, and little by little these men will be doing the real engineering work of the Navy. One day they will realize this fact, and they will naturally ask for the position and pay due

to their responsibilities, and so the old troubles will again be met with.

"When this is borne in mind it will be well understood the dismay with which the new policy of the British Admiralty is regarded, relative to this splendid body of men, and that it is considered that there is "a serious danger to engineering efficiency in the policy of lowering the status of the artificers, and in placing stokers as engnie-room watch keepers, instead of the present mechanically-trained and skilled engine-room artificers."

To sum up the matter: that the future officers of the Navy should begin their careers together and have identically the same studies to begin with, is an excellent idea, and the foundation thus laid should be a good one, but naval engineering is too large a subject for it to be shared with all the rest of the subjects that a naval officer's career embraces; it requires *all* his efforts, *all* his aims, and the most of his time, and must not be considered merely one of several subjects and by no means the most important of them.

Let the matter be looked at fairly; the time a naval officer spends in the engine room after he goes to sea is just so much time lost to him, and it had far better be employed in perfecting his practical knowledge of seamanship, navigation, pilotage, gunnery and torpedo work, and surely any one will agree that these subjects are more than sufficient to take up his whole time.

In like manner the time an engineer officer spends in acquiring the practical knowledge of the above-mentioned subjects, is just so much time lost to him, and any true engineer will tell you that life itself is not long enough for him to acquire a full knowledge of his profession and all it embraces; he is ever learning, and the hours of the day available are never sufficiently long enough for his practical work and studies.

There is the work of the executive officer, who should have full command of the ship as a whole and control of the men of his department, and there is the entirely distinct work of the engineer officer, who should have control of the men of

his department. The duties of these two are quite different, no good can possibly come from mixing them up together, and it is an all-round loss, and the sooner it is recognized that this is so, the better it will be for the efficiency of any navy.

The engineer should be trained as such, he should devote his whole life to his profession, and he should be an engineer first, last and all the time. In this way only can real progress be maintained.—"The Steamship."

ENGINEERING AND SHIPBUILDING.

Mr. James Denny, as President of the Institute of Marine Engineers, London, delivered his address at the opening meeting of the session on 5th October. Mr. Denny is a member of the well-known Dumbarton firm and is one of the greatest living authorities on Marine Engineering and Shipbuilding. He took for his subject some recollections and lessons and their application, drawn from an experience of fully forty-three years of marine engineering. He said, the changes that have occurred during this period, the advances that have been made in marine engineering, will undoubtedly compare with the changes and advances made by any other industry in the country. Perhaps the progress during the period being dealt with may be illustrated if we take two vessels, both for the same owners, the British India Steam Navigation Co.; one of these, the *India*, built in the early sixties, and the other, the *Rewa*, built two years ago. The *India* was 230 feet long by 30 feet beam, about 1,000 tons, and the *Rewa* 455 feet long by 56 feet beam, and about 7,000 tons. The *India* was fitted with one simple two-cylinder engine, 46-inch cylinders by 3-foot stroke, horsepower about 800; the water consumed per I.H.P. must have been approximately 30 pounds, but no accurate observations were then taken. The *Rewa* is fitted with three turbines with a shaft horsepower of about 10,000, and the water per shaft horsepower is 15 pounds for all purposes at the maximum speed. The *India* had two flat-sided boilers for 25

pounds pressure, with natural draft; the *Rewa* had two double-ended and four single-ended boilers of the cylindrical type, 155 pounds pressure, with forced draft. The speed of the *India* on trial was about 10 knots, and of the *Rewa* touching 19 knots. The *India* was the typical vessel of her fleet in her day; you will note that since then the tonnage—taking these two vessels as a comparison—has been increased sevenfold, the speed practically twofold, and the power fully tenfold. These are the broad, bare facts and they show a sufficient advance, but in detail the differences are even greater. In the *India* the engine-room auxiliaries consisted of one steam donkey pump and one hand pump, while the number of pipes in the machinery space was in all seventy; in the *Rewa* there are thirty-five auxiliary pumps and engines of various kinds, and 960 lengths of piping. The *Rewa* was fitted with hydraulic gear, electric light, refrigerating machinery, all of which were unknown forty years ago.

In the period under consideration, we have come, then, from the simple engine with jet condenser and 25 pounds pressure to the same engine with the surface condenser, then to compound engines with 60 pounds pressure, then to triple-expansion engines with 160 pounds pressure, then to quadruple-expansion engines with from 200 to 220 pounds pressure, and now to turbines, with a possible development of triple or quadruple engines in combination with turbines. The steam turbine, especially for marine purposes, is still in its infancy, although a very sturdy infant it has grown to. Practically all marine turbines, so far, have been of the Parsons' type, but there are others, notably the Curtis, an American invention, for which excellent results are claimed. Mr. Parsons will be entitled to and receive all the honor due to the pioneer who has fought the fight and borne the stress that pioneer work inevitably necessitates. All others must simply be followers in his footsteps and reapers of profit by the good work he has accomplished.

It has frequently been suggested that some inspired engineer would evolve a system of gearing that would be lasting and

reliable, not too noisy, and would not absorb in friction more than say 10 per cent. of power, turbine engines would be capable of application to any speed of vessel and to any size of propeller; you could then have a high-speed turbine and a low-speed propeller, which is the ideal condition for marine propulsion. This condition it is considered may be met in another way, which you will find fully described in a very interesting and capable paper read recently by one of your members, Mr. Durtnall. The system consists of a fast-running turbine driving a small dynamo, the latter again transmitting its electrical power to and driving a large slow-running motor on motors coupled directly to the propeller shaft or shafts. This arrangement does not eliminate the loss caused by the friction of the thrust of the propeller, as is the case in the turbine, and as also, by the way, would not be the case in any system of gear-driven propellers; otherwise one cannot but fear that the cost of this electrical system of propulsion will tell against it. A concrete case was recently put before a firm of electrical engineers who were strong advocates of such a system, but not Mr. Durtnall's; it was proposed to fit it in a ship, duplicate of one already at work with triple engines; the problem was the worst possible from the point of view of the advocates of the new system, but it was very carefully gone into and finally abandoned on account of the very considerable extra cost, and the doubt that existed if this would be met by the promised saving in coal consumption, even if the latter were attained.

There is still Mr. Parson's latest system to test in the adaptation, or rather partial adaptation, of turbines to low-speed vessels; he claims that a considerable economy will be effected by using a higher vacuum than in the case of ordinary machinery, and by interposing between the main exhaust of the ordinary engine and the condenser a turbine driving an auxiliary propeller; that thus he will utilize the final expansion of the steam, which is largely lost in the ordinary engine, due to the smallness of the passages between the low-pressure cylinder and the condenser. There may also in this system be some gain due to the consequent less unequal temperature in the low-

pressure cylinder, but that need not be gone into here. This system will be practically tried in a short time in a vessel for the New Zealand Shipping Company, and also in one now launched for one of the Atlantic lines; the results will be awaited with much interest by all interested in shipping. It is quite clearly understood that the crux of the problem is the relative efficiency of three propellers as compared with two, and this can only be determined by such practical experiments as are going to be made. Land installations have shown that the turbine, as arranged above, will give the economy claimed. Even if the first of the three propeller arrangements does not give the results expected, a modification of the stern in the vicinity of the propellers, and of the propellers themselves, may finally bring them about. In any case, the experiment will be a most interesting one, and the owners who have sanctioned it are entitled to every credit for their enterprize.

As has already been said, the turbine is still in its infancy, and this question of the propellers for turbine engines is one which perplexes all who have studied the matter. The best practical remedy seems to be to peg away at trials, obtain all possible data, and tabulate and analyze such data carefully for future use; by this means in time there will be obtained the power of arriving at the best possible results under any given conditions with at least some fair degree of accuracy. You all know that as the turbine increases in the revolutions which are practicable in marine work its efficiency increases; to obtain high revolutions the propeller sizes must be cut down, but this again decreases their efficiency, and the difficulty has always been and still is to strike the crossing lines of propeller and turbine efficiencies, so as to obtain the best combined result in terms of water used, or in what is equivalent, coal consumed into the speed of the vessel. Coal consumed per shaft horse-power is not a measure of efficiency in the case of turbine-driven vessels; the only basis is as already stated—coal consumption in relation to the speed of the vessel, as is indeed the case with ordinary engines.

You know in a general way that turbines as at present con-

structed are not suitable for low-speed vessels, but the reason why this should be so may not be quite so clear to you. You will best understand the reason perhaps by an illustration, always bearing in mind that the peripheral clearance of the blades and dummies is the important factor in the economical working of turbines. Take two vessels, one with a speed of 22 knots and the other with a speed of 12 knots, each requiring 10,000 horsepower for this speed. Design the propellers in each case on the usual basis for turbine-driven vessels, and make the turbines to correspond. In the case of the 22-knot vessel you will have propellers about 5 feet diameter running at nearly 700 revolutions, and in the 12-knot vessel the corresponding figures will be 13 feet diameter and 110 revolutions. Turbines corresponding to these revolutions will have such clearances that in the case of the slow-running vessel the clearance will be about five times as great as in the quick-running vessel. This clearance and its consequent leakage is the cause of want of economy in turbines of vessels running at slow speeds. A high blade in proportion to the diameter of the rotor, which is not admissible in such vessels, seems to be essential to economical working of turbines. While dealing with clearances, your attention may be called to an ingenious and simple invention recently brought out by the Mr. Parsons, which he calls "tipping the blades." By this system, which will reduce the blades to a minimum section at the very point, it is safe to run turbines with much diminished clearance, and so increase their economy.

The past has seen great changes in our business—what does the future hold for us? Apparently, at least, there is to be no standing still. The combination engine and the turbine-driving propellers by electrical transmission have been already referred to, but there are other systems that have been suggested and advocated with at least some degree of reason; these are internal-combustion engines, gas engines using producer gas, and oil engines. The first and last are used successfully in vessels such as racing launches and craft of small size, but matters are hardly ripe for their introduction on a

large scale; the gas engine has also been given a trial, but the results seem so far to be inconclusive. The extended use of the water-tube boiler in vessels where weight is a serious consideration is one of the problems that must be solved sooner or later. Small and tentative experiments in this direction are even now being made by two enterprising bodies of shipowners, the South-Eastern and Chatham Railway Company, and the Irrawaddy Flotilla Company. If these experiments are successful, considerable modifications will take place in Channel and light-draught vessel practice.—"The Steamship."

COALING AND COAL ECONOMY.

Of the many important arrangements affecting the efficiency of a warship, one of the most difficult satisfactorily to provide for is the reception of the coal into the bunkers, its stowage, and its distribution subsequently to the furnaces. The conditions imposed by ship construction, and warship construction in particular, make the problem the antithesis of that of a shore plant where mechanical devices alone transport the coal from the railway truck to the furnaces. The subdivision of compartments so essential to the safety of a warship makes a number of coal bunkers inevitable, and in a large vessel it is usual for there to be at least twelve bunkers—four lower and eight upper—to each boiler room; each of these bunkers must have means of filling from above, for trimming from the upper to the lower, and to some extent for transference of the coal in a fore-and-aft direction. The number of openings in the decks and bulkheads must be as few and their size as small as possible, and they must be closed by watertight scuttles and doors capable of being worked easily and closed rapidly, in case of collision or damage, from at least one easily accessible position. As a necessary consequence of these conditions, the transfer of coal from a collier or from the dock side to the bunkers is almost entirely a matter of manual labor, while the subsequent transference from bunkers to furnaces is exclusively so.

The recent increases in speed of warships and the consequent increases in power involve correspondingly greater coal consumption, and unless the speed of coaling can be augmented more time must be spent in this arduous and uncomfortable operation. In our issue of July 10th we published a report of Admiral Evans, of the United States Navy, on the fleet under his command, containing some interesting observations on the question of coaling. He considers the subject of such importance as to merit the most careful consideration, from the operation of bagging the coal to its final trimming in the bunkers. A complete review of the subject shoulld include the design of colliers to make them fit the average battleship, so that the greatest number of men and hoists may work at the same time. The problem is, as Admiral Evans points out, one of great tactical importance, for a vessel during the time of coaling is not an effective unit of a fleet. In our own Navy there have been many remarkable coaling performances, and much emulation exists in the ships of the various fleets to show a smart coaling record. The time taken, as shown by the returns, does not, however, represent the time during which the ship is out of action. There is the preliminary work of rigging coal chutes, where, as in a number of cases, they are portable, and these same chutes have afterwards to be unshipped and stowed. Many of these impedimenta could not be left in place without interfering with communication along the decks, and their removal is therefore necessary before the vessel resumes her character as an efficient fighting machine. There is, further, a good deal of trimming in the bunkers to be finished after the last bag has been hoisted on board, and this trimming must all be completed before the last of the armored scuttles can be closed.

As a moderate estimate, a battleship requiring to refill bunkers may be considered *hors de combat* for twenty-four hours, and for at least half this time to be incapable of giving chase at full speed, while if the coaling appliances on the ship or collier are indifferent these times may be greatly exceeded. History repeats itself, and it is quite possible that under mod-

ern conditions we may see a repetition of the chase which Nelson made after Villeneuve. Absence of definite information due mainly to Nelson's lack of frigates made this pursuit abortive. In the modern instance, should it occur, coal endurance and the ability or otherwise to coal with rapidity will be the determining factors. The tactical advantage of rapid coaling which Admiral Evans emphasizes is thus very great, but except in points of detail it is difficult to see how any advance is to be made. The coal has to be bagged in the hold of the collier and trimmed into the bunkers, and while these operations are essentially manual, quickness of coaling is mainly a matter of physical endurance on the one hand and organization in the routine of shooting the coal into the various bunkers so as to avoid blocking the chutes on the other. The intermediate operation of hoisting on board can in most cases be done much more quickly by the colliers' winches than the bags can be filled or the bunkers trimmed.

As we cannot reasonably expect any great advance to be made in the speed of coaling over these obtaining at present, the questions of bunker capacity and economy of the propelling and auxiliary machinery become of additional importance. In our most recent ships bunker capacity has been largely increased with the disadvantage pointed out by Sir William White, that the sinkage from normal to deep draught has been also increased, a rather serious disadvantage affecting the efficiency of the armor belt, but an inevitable part of the price which has to be paid for increased speed. Another factor in this problem is the use of oil fuel, the tactical advantage of which was demonstrated in the maneuvers of two years ago when the fleet under Sir William May using oil fuel easily evaded the pursuing fleet. The use of the double-bottom compartments for the storage of liquid fuel has undoubtedly contributed to the solution of the problem of obtaining higher speeds without sacrifice of radius of action.

The question of rapid coaling, as we have shown, mainly depends upon the human element; the question of bunker capacity is one of construction which does not permit of much

variation in treatment, and it is to the matter of economy of fuel consumption that all such discussions must inevitably lead. The vessel with the lowest coal consumption is invariably the best steamer; she will "get there" quicker and take less time to refill her bunkers than her less economical sisters. To refer again to Admiral Evans' luminous report, he says the variable performance of the ships of this fleet would indicate that this is as much a question of economy in the design of the engines and boilers as in the actual capacity of the bunkers, and in the succeeding paragraph he refers somewhat caustically to the performance of one of his ships which has no economical speed and burns over thirty tons of coal a day in port. Coaling a vessel with such an appetite as this must, indeed, be a Sisyphean task.

It would almost appear that we have reached a limit in the economy of the main propelling machinery of warships, as the coal per indicated horsepower has been practically stationary in the last decade, while owing to the multiplication of power-driven mechanical appliances on board, the consumption of coal for auxiliary purposes has sensibly increased. In spite of the cheery optimism of some of the advocates of the internal-combustion engine, it is to be feared that the prospect of reducing the coal bill of the main engines by gas-engine propulsion is still remote; but, on the other hand, there does not appear to be any great difficulty in the way of reducing the expenditure of fuel for auxiliary purposes by employing oil or gas motors, and, in fact, a start in this direction has already been made in our own Navy. The importance of economy of coal for auxiliary purposes is not often realized. In the hypothetical reproduction of the famous incident to which we have previously referred, the modern Nelson will be watching with dwindling bunkers while the modern Villeneuve is waiting his opportunity to escape, and when at length the chance arrives, Nelson may find that he has not coal enough left to give chase at full speed. A vessel so uneconomical as that mentioned in the report quoted will empty her bunkers in two months without having moved her screws, and she would be almost useless at some distance

from a coaling base. To be able to coal quickly when required is good, but to be able by superior economy to outstay a rival is better, and if the former merits careful study, the question of the economy of main and auxiliary machinery deserves to be made the subject of exhaustive research.—"The Engineer."

HEAT AND WORK.

The presidential address delivered in Section G by Mr. Dugald Clerk was a distinguishing feature in the proceedings of the British Association in Dublin. Mr. Clerk's reputation as an engineer first, and a physicist afterwards, is so high that a good deal was expected, and he has not disappointed expectation. It is an excellent thing that the young men of the present generation should have the history of that section of thermodynamics with which the industrial world is most concerned clearly stated. The precise nature of the achievements of such men as Carnot, Clausius, Rankine, Thomson, Joule, Regnault, and many others named by Mr. Dugald Clerk are, we fear, often forgoten by too many of the present generation. The address of the President of Section G will do much to place the great physicists of the last century in their proper position.

We shall not attempt to follow Mr. Dugald Clerk into details. We shall confine our attention to one point only, on which, indeed, Mr. Dugald Clerk based most of his address, namely, the conversion of heat into work. It will, we fear, be news to many students that the most eminent authorities of their day did not believe that as work was done heat disappeared. The theory which held possession of the scientific world for many years was that heat was an entity, called for convenience "phlogiston." Mr. Dugald Clerk states the nature of this belief in detail; and he goes on to show how slowly more accurate notions replaced a very convenient theory. In this connection, however, he has not done full justice to such men as Count Rumford, who by a classical experiment made by boring cannon, showed that heat was produced by the work

done by the horses who turned the boring tool. Again, although it is true that Tyndall and Donkin lived after the period covered by his address, he might have pointed out that the former, by his lectures and by his books, did much to establish and popularize the theory that heat is a mode of motion—words far more pregnant than they appear to be at first sight. To the late Bryan Donkin, Jr., belongs, again, the credit of being the first to show in actual factory practice the disappearance of heat into work in a steam engine. This he did by measuring the rise of temperature and the volume of water required to condense a known weight of steam passing through a compound beam engine driving the tools in the Bermondsey works of his firm. The condensing water was passed through a notch-board in a quieting tank, and every effort was made to get accurate results. A difficulty lay in the fact that there are six recognized coefficients for discharge over weirs, none of which agree. The differences in result are, however, small; and although an element of uncertainty existed, Donkin was able to prepare balance sheets which not only proved beyond dispute that heat was converted into work, but that it was possible to express the efficiencies of steam engines in entirely new terms. In the present day all this is familiar even to the first year's student. It would be a pity if credit was not awarded to the man who first showed how the facts could be utilized by the engine builder and the steam user.

Mr. Dugald Clerk had a good deal to say about specific heat. Within the last few years there has been doubt expressed as to the accuracy of much that has previously been accepted as absolutely true. Facts come to light and acquire an importance because they are apparently not consistent with other facts previously ascertained. A revision of theory is no doubt going on which may prove not a little helpful to the practical designers and makers of heat motors. Not the least remarkable feature of present-day thought is the possible revival of the theory that heat is a material entity. Not indeed a ponderable fluid, but a condition of a portion of the ether. Such a view has been more than hinted at by such men as

Lodge and Le Bon. Whatever may be said of this, it at all events is clear that so long as the true nature of heat is unknown, various theories will be advanced whose importance will be measured by the reputation of the men putting them forward. It seems to us that before any great step can be made in formulating a theory of heat engines, it will be necessary to settle something about the way in which heat is converted into work. Up to the present moment the words are used in a very restricted sense. There is no accurate concept formed of what goes on. We say that heat is a mode of motion. The words do not explain what heat is; they only assert that when a body is heated its particles are put into motion, and that when it is cooled they lose motion. Are the constituent molecules wholly inert, moved backwards and forwards by "heat," as the shingle on the sea shore is moved by the waves? Or is the motion a something inherent in the gas? The electrical theory of the present day only moves our puzzle one step backwards. All that can be said at the moment is that the true definition of heat is that it is a mode of motion of the ether, made manifest to us by molecular vibrations of matter.

Leaving such speculations on one side, we may at least say that since the days of Clerk-Maxwell it has been fully accepted that the pressure of a gas is due to the collision of its molecules with the surface of the containing vessel. This being so, it is easy to see how the energy of, let us say, steam behind a piston is converted from one form of work into another. What is true of a multitude of molecules is true of one. Let us suppose an engine cylinder in which the face of the piston and the cylinder cover are absolutely hard, and that inside we have a ball perfectly elastic, bounding backwards and forwards between the piston and the cover; there is no loss of energy in the ball, no conversion of heat into work. If, however, the piston moves, the recoil from its face will be less rapid than the impact, and the repetition of the process will result in a continual loss of motion by the ball. If the operation could be carried far enough the ball would entirely lose its motion.

Absolute zero would be reached. To ascertain the energy in one ball would not be difficult. To ascertain that in countless myriads of them is not so easy. The "specific heat" of a gas really means the measure of the energy which is represented by the motion of its particles. The method of the conversion of the work in a pound of steam into the work done by the rotation of a crank shaft is obvious enough. It is in effect that of a Pelton wheel. It is not until we come to explain how the molecules are put in motion that we are in difficulties. It is here, of course, that the ether-wave theory comes in, and that is far from complete. Just as there are waves of "dark" light, so there are "heat" waves which are absolutely cold. Pure radiant "heat" waves have no temperature. Interstitial space is at zero. It is conceivable that ice might be placed near the sun without dissolving. A lens of ice may be made to act as a "burning glass" without itself melting. It is the collision of the waves with solid bodies that produces what we term heat. When we come to examine the old-time notion that heat was a separate fluid, we can easily see that although the theory was incompatible with certain facts, yet that it is by no means certain that if we leave out the word "fluid," and speak only of a separate entity, we shall not be nearer the most recent views of the physicist than we shall be if we confine our definition of heat to "a mode of motion." Mr. Dugald Clerk has given us the last word on the subject from the engineer's point of view: but the world does not stand still, and the research and inquiry which he advocates may have results which will modify our views on thermodynamics in more ways than one. It is at least certain that so far no rational theory of the production of energy by the explosion of gases has been formulated, if we exclude that of Dr. Le Bon as untenable.—"The Engineer."

WATER HAMMER.

The engineers who have not heard of water hammer must be very few; the number of those who understand what it is is still fewer. Stop valves and cast-iron steam pipes are burst

now and then with more or less violence. When there is no other way of accounting for the disaster, it is put down to water hammer. The theory of water hammer is quite simple. A quantity of water accumulates in a steam pipe. The stop valve is opened to start the engine. The rushing steam picks up the water and drives it with such violence against the partially-closed stop valve, or a bend in the pipe, or some other obstruction, that the metal yields as it would to the blow of a heavy sledge hammer.

Such an explanation seems quite obvious—a theory to be accepted without question as final. Unfortunately this is not all. The explanation leaves some questions unanswered—certain problems unsolved. For example, why should there be a a violent rush of steam when the stop valve is scarcely opened? How does the steam pick the water up off the bottom of a steam pipe at one moment and flow quietly over it at another moment? Has anyone ever attempted to ascertain the force of a blow which can be given by the water in, say, a 6-inch steam pipe? Model tests with glass tubes have been carried out by Mr. Stromeyer which truly show a water-hammer action; but these are qualitative experiments, so to speak, not quantitative. No numerical expressions can be deduced from them. In practice the means usually seem to be inadequate to the end. It would appear that there is not water enough or velocity enough to smash up pipes and valve chests in the way in which they undoubtedly are smashed.

A recent Board of Trade report presents us with an interesting example of water-hammer problems. We have some facts which are not easily explained, and, as a matter of fact, no attempt has been made to explain them by Messrs. Longstaffe and Gray, the Commissioners who have investigated the case and reported on it. These gentlemen admit that the phenomena of water hammer are "not all even yet known to engineers," and it will, we think, be seen before we have done that they have good ground for this somewhat apologetic statement. The facts are easily stated. A 3-inch sluice stop valve burst about 12·35 P. M. on the 28th February, in the New

Foundry Department of the Stanton Ironworks Company, Limited, Stanton, Ilkeston. James Riley, laborer, and Christopher Shaw, fitter, were killed. Thomas Smith, assistant foreman fitter, Edward Martin, Frederick A. Tansley and John Keeling, fitters, and Herbert Whatley, engine driver, were seriously injured. The valve was made by Messrs. Glenfield & Kennedy, and it will save time to state here at once that there was no flaw or defect in the valve; that the cast iron was of excellent quality, and that two years ago the valve had been tested, when new, up to a pressure of about 400 pounds. The boiler pressure under which it worked was about 160 pounds. Two engines are on the premises of the Stanton Ironworks—one the "regular shop engine," another a duplicate or stand-by engine. The regular engine was going to be laid by for repairs, and the duplicate engine was started. Then the explosion took place. The steam which the company requires for its engines is supplied by seven Lancashire boilers worked at a pressure of 160 pounds. That steam passes first through a range of pipes 9 inches in diameter, and from that range is carried through another range of cast-iron pipes 6 inches in diameter. The last mentioned range, in its turn, communicates with another range of pipes 4 inches in diameter, and it was upon this range of 4-inch pipes that the valve in question was placed. Upon that range of pipes there is a drain valve for the purpose of carrying off from them, and clearing them of, such condensation water as is created. The open end of the drain pipe which drains these 4-inch pipes is about 30 feet distant from the valve, and discharges into an old disused flywheel pit. The stop valve is placed with the spindle horizontal. A species of expansion loop is formed on the steam pipe, the level of which last is below that of the stop valve. The descending elbow of the loop is a couple of feet long, and no means of draining it exist. As soon as the valve is opened any water in the elbow will pass into the engine, but the quantity which can collect is very small, and lying quietly on the valve, can do no harm. Now the main steam pipe is very long, and condensed steam would no doubt accumulate in the 4-inch sec-

tions if the drain cock was closed. The men in charge are said by the Commissioners to have been highly intelligent, thoroughly understanding all about the engine and the piping, and they did what they had often done before—they opened the drain cock, and one of them descended into the wheel pit and satisfied himself that water and steam were coming out before he attempted to open the stop valve. So far as was known there was no water in the 4-inch pipe at that time; but the 4-inch pipe was joined by a tapered reducing piece to the 6-inch pipe, and it appears to have been possible for water to have "ponded" on the bottom of the 6-inch pipe until it rose high enough to flow over into the 4-inch section. The maximum depth could only have been 1 inch. How far back in the 4-inch pipe the ponding could have extended we have no evidence to show.

Be this as it may, the Commissioners hold that this water was picked up by the steam, flung violently through thirty feet or so of 4-inch pipe with five sharp bends in it, ultimately striking the valve chest with such force that it burst it. We do not say that this did not happen, because we do not know whether it did or not; but we do say that it was a curious and unlikely performance if it did. It is quite clear that there must have been a very violent rush of steam to project the water in this way. Let us see whether the conditions were likely to set up this rush or not.

The Report is far from lucid; indeed, in certain places it is hard to understand. There were two drain cocks, one on the 6-inch and the other on the 4-inch pipe, and both these were, we are told, open for about an hour before the explosion took place; but nothing is said as to the inclination of the steam pipe, and there is no means of knowing whether "pocketing" took place or not. In the elbow before referred to right over the stop valve lay, it is supposed, about half a gallon of water, all the elbow would hold. It appears that from the first—that is to say, for at least an hour—the boiler stop valves had been open, and the steam pipe was therefore charged with steam. In fact, it seems as though the regular shop engine which was

nearest to the boilers had been at work all the morning, and was only stopped when the duplicate engine was to be started. The valve wheel was moved by the foreman fitter Smith, who was badly scalded. He turned the wheel about an inch, opening the valve a very little, while four men barred the engine round. Smith very cautiously opened the sluice valve a little further, and then the valve chest burst. The engine, be it observed, had been drained and warmed up just before, so that no rapid condensation of steam could have taken place. Nor is it clear that there was any water in the valve chest or elbow. Even if the stop valve had been opened wide suddenly, as the engine could not take the steam, for it had not started, it is difficult to understand in what way a rush of steam might have been set up.

It is quite clear from the Report that the Commissioners found themselves in such a position that they must say that the smash was due to water hammer, or else admit that they were unable to furnish any explanation, for they write all through, with commendable caution, "we think;" and they further protect themselves by stating twice that engineers do not understand the phenomena of water hammer. As it was admitted that the three-quarters of a gallon lying on the stop valve could do no particular harm, even if it was there, they had to find water elsewhere, and this they did, as we have shown, in the 6-inch pipe. But the water could not have been there if the drain cock was open. To get over this difficulty they say that they do not believe the direct and positive evidence of two witnesses that the cocks were open, maintaining that the men were mistaken. The Commissioners, be it remembered, admit all the time that these men were highly intelligent, truthful, straightforward and competent. Our readers must form their own opinion as to the value of the assumption that the drains were really shut. We ourselves see no reason for rejecting what was really first-class evidence.

We have no explanation to offer. A most searching inquiry results, we think in leaving the explosion unexplained. The circumstances were sufficiently startling. Here we have an en-

gine started as it had been started many times before. It was in the hands of men who were, it is admitted, above the ordinary run of fitters and engine drivers. Every legitimate precaution appears to have been taken. The Commissioners have no fault to find with any one. On the contrary, they have nothing but praise for all concerned. The arrangement of the steam pipes they say was practically satisfactory. They cannot suggest an improvement. The precautions for draining the pipes were all that could be desired. We reserve for the last their explanation of what took place. We give their own words: "When the steam was admitted to the engine by Smith, we think that the water standing in the 6-inch pipe was driven and forced against the column of water standing immediately above the valve, and that the 'water hammer' thus produced fractured it." A moment's reflection ought to have been sufficient to show that before any rush of steam could have taken place, the water on the stop valve must have passed into the engine. There is no scrap of evidence that there was any water there; and, lastly, it may be pointed out, that the projection of a "lump" of water at a high velocity round five nearly right-angled bends appears to be a physical impossibility. Water-hammer action almost always means a straightforward blow, smashing the first obstacle, which in this case was a bend. Velocity would have been lost at each bend—a fact which the Commissioners seem to have overlooked.—"The Engineer."

THE CORROSION AND DECAY ON METALS.

Lecture by MR. J. T. MILTON, Member of Council Institute of Marine Engineers, at the Franco-British Exhibition, September 5, 1908.

The subject of the lecture tonight is of such importance, both to the constructive engineer and also to the engineer whose business it is to attend to the maintenance of the structures placed in his charge, that no apology is needed in bringing before the Institute of Marine Engineers. To the constructor because he has to provide an excess of material in his design to

allow for an inevitable deterioration which he knows will take place; and thus at the outset, and right through the useful life of the structure he creates, it is handicapped by having to carry more weight than would be necessary if he could ensure that no weakening by decay or corrosion would occur. To the engineer in charge because his every-day work includes the taking of precautions against the failure of each one of a large number of small details, the failure of any one of which, owing to the interdependence of so many parts of the mechanism, may produce serious consequences out of all proportion to the seeming importance of the detail in question.

By far the most important material used in engineering structures is iron in its various forms of cast iron, wrought iron and mild steel, and unfortunately iron is one of the metals most liable to decay or corrosion. The corrosion of iron is almost but not invariably due to its affinity for oxygen, and the consequent formation of oxide or rust. Cases of decay of cast iron, however, occur, to which reference will be made, in which the formation of rust does not appear to be the sole cause of the trouble, but rather the formation of some soluble compound which is washed away or dissipated by the corrosive influence itself.

Although the formation of rust is of such a common occurrence, there is not by any means a concurrence of opinion as to the precise way in which rusting takes place. The presence of water seems to be essential, but water by itself will not rust iron. When bright iron is immersed in pure water which has been freed from dissolved air it remains bright for an indefinite period, but, given the access of air or oxygen in solution in the water, rusting almost immediately sets in. It is stated that the action of oxygen and water is comparatively slow except there is also the presence of a small amount of free CO_2, and that when this is present the rusting is much more rapid. It is on this account that in cases where oxygenated water has necessarily to be kept in contact with iron the presence of a little caustic lime in the water is found to be preservative, the lime (calcic oxide) has a strong affinity for CO_2, forming

calcic carbonate, and prevents the gas from remaining in the water.

In the cases of many metals which are readily oxidizable (lead is an example) it is found that when the outer surface of the metal has combined with oxygen the thin film of oxide so formed prevents the access of further oxygen to the metal and so stops further corrosion. In the case of iron, however, this is not the case. It is unfortunately true that iron once rusted corrodes more quickly than clean iron when exposed either to moisture with access of air or oxygen, or when exposed to moist air. The reason for this is obscure; but it has been said that the oxide of iron formed (Fe_2O_2) will under certain conditions, either of temperature or moisure or both, occlude or separate out and absorb from the air an excess of oxygen, whilst in other conditions of temperature, etc., it gives up the oxygen so occluded. Evidently if this is the case, when the occluding conditions occur the coating of oxide can most readily obtain the oxygen from the side nearest the air, whilst when the reverse conditions occur it can equally readily divest itself from the excess of oxygen by yielding up some of it to the contiguous iron on one side, as by giving it up to the air on the other side of the film. Whilst this is a possible reason, it may not be the only reason for the continuous oxidation of the iron covered by a film of oxide. It may be that the oxide itself is not an absolutely coherent solid mass such as the ordinary senses imagine metals to be, but it may really be of a porous structure, with openings or vacuities sufficiently large for molecules of oxygen to freely penetrate them and so obtain access to the iron underneath, or even sufficiently porous to contain sufficient moisture to support an electrolytic action, to which reference will presently be made. However, the important fact remains that a coating of rust once formed on iron is no protection whatever against further oxidation, but the reverse, so in all cases where rust has once formed it is best to remove it as soon as possible. Evidently the best way to prevent iron from oxidation is to prevent the corrosive influences from coming into contact with it, and for this purpose,

whenever the use of the structure will permit it the surface should be covered with something to keep air and moisture away from it. The most usual protection is paint, whilst cement, asphalt and galvanizing are also employed with more or less success.

The subject of paint is one very well worth study by engineers, but is too complex to be dealt with in the present lecture beyond making the statement that an ideal paint is one which can be easily spread on the iron, will not flake off, and will quickly dry into a hard coherent coating so continuous or free from porosity that it will not permit of the passage of moisture or of air through it. Such a paint has not yet been found, although many good paints when properly put on do protect in a very marked degree the metal under them from corrosive influences.

Portland cement is usually employed only for parts where water is always present, and experience with the inner surfaces of the bottoms of iron and steel ships shows that where it has been put on of sufficient thickness to endure durability it effectually prevents corrosion both when applied originally to the bare iron and to iron previously coated with good paint. The thin coating of "cement wash" applied to parts which cannot be cemented in the ordinary way, however, cannot have the same good character given to it, as we see by the severe wasting which occurs to the floors and reverse frames, tank tops, etc., of vessels which have been treated in this way whilst building.

Galvanizing is a process of covering the iron with a thin film of zinc, and is very efficient for a time in most cases in which it can be applied, and where only atmospheric influences have to be resisted; but after a time it, the zinc, becomes wasted and its preservative effect is lost, and then as the iron cannot be again galvanized the further preservation must be attempted by means of paint.

At first protection is afforded simply because the first coating of oxide which the zinc surface acquires protects the metal from further oxidation, but this in time wears off, more oxide

forms, and at last the zinc coating, in spots, becomes completely worn through, leaving the iron surface exposed. The preservative effect, however, has by no means been lost, and the iron in the exposed parts is still preserved by the zinc remaining on other parts through what is called galvanic action; and not until the zinc has practically disappeared from the whole surface does the now exposed iron begin to corrode.

If two dissimilar metals are immersed in a corrosive liquid, or exposed to a corrosive atmosphere which will act on both of them, so long as they are not brought into electric contact each is acted upon in precisely the same manner as if the other was not present; but if the two metals are brought into electric union, then the whole of the corrosive influence is transferred to one of the metals, the other being protected; at the same time an electric current is set up which proceeds from the most corrodible metal through the liquid to the other metal, and thence through the electric path or connection back to the most corrodible metal. In the case of a plate of zinc and one of iron being both immersed, say in salt water and electrically connected the iron will not corrode, but the zinc will. In common language, the iron is protected at the expense of the zinc. This is the principle upon which depends the preservation of boilers by means of zinc plates placed in them. In a worn place of galvanized iron there is electrical communication between the iron and the remaining zinc, and so the iron is preserved at the expense of the zinc so long as any remains.

At the same time let it be noted that there is a galvanic current produced flowing through the electric connection from the protected metal to the more corrodible metal. The energy of this current is proportional to the chemical action, which is represented by the corrosion.

Although we have taken iron and zinc as our illustration, the same results hold with any two dissimilar metals, one at least of which is acted on by the corrosive fluid, and we constantly meet with cases in which dissimilar metals placed in electric contact at one part, and subject to the same corrosive action at other parts, set up a galvanic action which results in

the protection of one of the metals at the expense of the other. Even when two metals so much alike in chemical and physical properties as wrought iron and mild steel are used together, the slight differences between them lead to some galvanic action when they are exposed to suitable conditions, and usually the wrought iron is then preserved at the expense of the mild steel.

Now let us take a glass vessel and put in it a liquid of slight corrosive power,* and insert in it two plates, one of iron, the other of copper, and, so long as there is no electric contact, both plates are acted upon in the manner peculiar to themselves and to the corrosive liquid; but connect the plates, say by a wire, and we have at once a current set up as indicated by the arrows, and at the same time the iron plate is more actively corroded than before, whilst the copper is preserved. If now instead of I and C being both immersed in the same liquid, which it will have been observed conducts the current from I to C, they were immersed in separate cells which have no electric conductivity between them, then no current is set up and no protection is afforded to I by Z even although they are connected by the wire. For the galvanic action to take place, therefore, it is essential that the current should flow from I into the liquid and from the liquid into C. This can be arranged by immersing a connection B in both cells, and we then have the complete galvanic action produced. Note that the corrosion takes place where the current leaves I to go into the corrosive liquid. Now instead of the right hand cell let us suppose we have a source of elctricity supplied altogether distinct from that obtained through the plate C, so that we get a current entering I of the same intensity as before, and the same intensity of current consequently leaving I into the liquid, I will then be under precisely the same conditions as before in being exposed to a corrosive medium and in having a current passing through it, and it will be found that it cor-

* In these experiments the liquid was water with one part of nitric acid to two hundred of water, and a little common salt to increase its electric conductivity, and a small quantity of ferrocyanide of potassium. The latter gives an intense blue coloration when there is a trace of iron present.

rodes exactly as before. We see, then, that one condition to ensure corrosion is that a metal shall be exposed to a corrosive influence, and that a current shall flow *out* of the metal into the corrosive liquid. This action is the cause of much trouble due to the wasting of water and gas pipes, etc., in the earth by currents due to leakages from electric mains, and from the return paths of electric rails in tramways, etc. We must return to this question of electrolysis by and by when dealing with the deposition of scale on screw shafts, but at the present it is enough for us to note that all that is required to set up corrosion in a piece of metal is that a current, produced somehow, either by the corrosive influence itself or by some altogether extraneous means, does leave the metal where it is in contact with a corrosive element, and that then the amount of corrosion so produced is proportional to the amount of the current and to the time during which it acts. It is evident that if the same current is distributed over a large surface so that its intensity per unit of area is small the corrosive effect or loss of weight of the metal per unit of area will be less than if the same current is concentrated on a smaller area. Hence we see that if the surface of the metal is for any reason generally obstructive to the flow of the current, but at the same time certain parts of it are less so than others, so that these parts conduct more than their own share of the current, then these parts will receive more than the average of the resulting corrosion, or in other words they will become "pitted." It is this which leads to severe pitting in places where paint or protective scale has been accidentally locally removed, and it points to the importance where scaling has to be done of having it thoroughly done, otherwise the freshly-cleaned parts will receive all the corrosive influence which ought to have been distributed over a larger area.

We will now take two cells and a battery, and we will arrange matters so that in one cell the current from the battery enters the iron plate to be corroded, flows through the liquid to the other pole, which we will make of carbon, which is an incorrodible material, thence to a similar carbon pole in the second cell, then through the liquid to another iron plate, and thence

back to the battery We shall find that in the first cell, as before, corrosion occurs on the plate where the current leaves the plate to enter the liquid, but in the second cell where the current enters the metal from the liquid no corrosion whatever occurs, even although there is precisely the same current passing through both cells.

In the next experiment we will make the current concentrate a more than usual proportion on one particular point, and in this case we shall find the iron in a short time will be pitted right through.

Two instances only will be mentioned of sources of current affecting corrosion on board ship: First, electric machinery; second, the differences of temperature to which different parts of the structure are subjected. Electric leads are constructed on two systems, the single wire with hull return, and the double wire. In the single wire the current leaves one pole of the dynamo and is distributed as required by a system of branching mains. From the lights, etc., it is returned to the structure of the ship, and thence to the other pole of the dynamo. The conductivity of the steel hull of the ship is so enormous that it seems at first sight that absolutely no current could leave it between the points where it enters and the connection to the dynamo pole; but where there are several ways open for a current to traverse, it is known that it will divide itself between all of them, the portion flowing through each path being inversely proportional to the resistance of that path, so that some current, however slight, must flow through every possible path between the electric-light connection and the dynamo pole; and if one such path lies along a way where the current will leave a corrodible metal to enter a corrosive medium, some corrosion will take place there. With a leaky cable the leak similarly distributes itself over every possible path to the hull of the ship, and it may be that in some cases it finds a short path through some pipes or fittings which it corrodes, and which otherwise would be unaffected. In the double-wire system a defect in one cable only will not leak electricity unless there is a means for the electricity to return

to the other cable. If there are defects in both cables, then the leakage from one to the other divides itself between every possible course. In this way, with either system, we get what engineers on board ship term "stray currents," very difficult to detect, but very serious in the long run, not so much on account of the loss of power of electric plant they represent, but because of their sure though slow action in effecting the corrosion of some part of the vessel.

It is, however, perhaps from the differences of temperature of different parts of the vessel that we have the most serious results ensue on board steam vessels. It is a well-known experimental fact that given two pieces of the same kind of metal electrically connected, but at different temperatures, the warmest will always be electro positive to the other, and if they both are in the same corrosive medium a current will flow from one to the other. It is in the double bottoms under the boilers that this finds the greatest illustration. Here we have all the conditions for corrosion. The upper part is heated by the boilers, the lower plates are kept cold by the sea. They are in communication by the floors, etc., and are surrounded either by sea water when the tanks are full, or by moist air when they are so-called empty. A current is set up and corrosion occurs. The remedy appears first to as much as possible prevent the differences of temperature by preventing the heat of the boiler from reaching the ship structure, and second by ensuring that there is no corrosive medium either of sea water or moist air in these spaces. This can only be done by ensuring that the spaces are kept absolutely dry. Thirdly, by paying particular attention to keeping these parts thoroughly protected by paint inside, and by paint or other means outside. These points are given much more attention to now than formerly, but they are so very important that they will bear repeating and emphasizing.

Another part of the vessel to which the same differences of temperature must affect the structure and set up currents is in way of refrigerating spaces. Here, however, the reverse conditions occur. The parts of the vessel hidden from view be-

hind the insulation are kept cooler than normal, and so they tend to be preserved instead of corroded; moreover, they are kept dry instead of moist, and on these accounts they do not corrode or give undue trouble or anxiety. The same influence of differences of temperature can often be seen in boilers. For instance, the shell of a donkey boiler, if corroded at all, will be found to be corroded on the side nearest the main boiler chimney, and to be free from corrosion on the other side.

So far we have spoken of corrosion as due to the action of a corrosive liquid or medium on the metal either under normal conditions, or intensified by electric current so arranged that the current leaves the metal to enter the corroding medium. Now for a moment consider the reverse action. Turning to our original experiment, we saw that if both the plates were by themselves corrodible in the liquid, when electric contact was made the one which was least corrodible was protected by the arrangement, and we also saw that it was not necessary to have two dissimilar metals to make the one corrode; a current, however generated, was sufficient to affect the same purpose, provided it was made to leave the metal. Now let us reverse the direction of the current, and we shall find that, provided it was made to enter the metal from the liquid, corrosion is stopped. This experiment shows that electric currents may be made to protect as well as to corrode.

So far our remarks have all been made to apply to the case of a metal of homogeneous structure, that is to say of which each and every point has the same physical properties. Let us see what will happen if the metal is not homogeneous. No metals are absolutely pure. How are the various impurities which exist in the metals actually distributed through the mass? When two or more elementary substances are mixed together we produce either one of three different kinds of arrangement of the individual particles. We may have first what is called a mechanical mixture, in which each individual particle of each substance has retained its own individuality and is merely mixed up with the other particles, and if we had patience enough we could again separate each from each. As an in-

stance, consider a mass of iron and brass filings mixed together as intimately as possible. Each particle of iron remains iron distinct from all the particles of brass, and the use of a magnet will be sufficient to again separate all the iron from the mixture.

Next we may have a chemical combination; definite numbers of atoms of each component unite together and form an altogether different substance with physical properties from either of the component parts. A chemical combination has the property that each part of it, however minute, contains precisely the same proportion of each constituent as every other part, whereas in a mechanical mixture we may have very considerable variations of the different constituents when we closely examine very minute parts of it.

Thirdly we have what is called a solution. As an example take a solution of salt in water. Here we have, when carefully examined, the same proportion of salt and water in each and every part, but the proportions, instead of being definite as they are in a chemical compound, may be anything ranging from the very smallest amount of the dissolved substance up to that particular amount which saturates the solution. (Under certain peculiar cricumstances it is possible in some cases to have a supersaturated solution, but this is always a condition of unstable equilibrium.)

We not only may have liquid solutions, but the same equable distribution of the one substance within the other, if in the solid state is also called a solution, but in this case it is generally called a solid solution. The three states of distribution of different elementary substances then are: (1) Chemical compounds distinguished by every part, however minute, being composed of precisely the same definite atomic proportions, and consequently being homogeneous; (2) solutions in which each and every part also is composed of precisely the same proportions, and the substance is, therefore, still homogeneous; but these are not atomic proportions and may be varied indefinitely below the maximum or saturated condition of any one of the constituents; and (3) mechanical mixtures in which, when

minutely viewed, the substance is not homogeneous, small measurable portions being composed wholly of one constituent and others of other constituents.

When we come to closely examine metals we find in them all three forms of these arrangements. As an example of a chemical compound let us take a yellow brass composed of about two atomic parts of copper to one of zinc. If the copper is first melted in one crucible and the zinc is then added, either by having been separately melted and poured into the copper, or even by being put as a solid into the molten copper, combination takes place with the evolution of a considerable amount of heat, and the resulting metal is altogether different from either of its constituents. It is perhaps not so ductile as the copper, but is immensely more so than the zinc. It is a different color from either of them and is stronger than either. Whereas copper can be worked either hot or cold, this cannot be worked hot—in fact it is a different metal altogether. If instead of taking two parts of copper to one of zinc we take about equal atomic quantities, and treat them in the same way, we obtain another chemical compound. Like the other it is yellow, harder than copper, and possesses considerable ductility, and is altogether different in its physical qualities from either copper or zinc. It is a true chemical compound.

Now instead of taking either of the proportions named, suppose we take some intermediate proportion, say 60 per cent. copper and 40 per cent. zinc, which is the composition of the alloy so well known under the name of "Muntz Metal." We still, on mixing the molten metals, obtain chemical action with the evolution of heat, but what really takes place is that we get actually a mixture of the two chemical compounds Cu_2Zn and CuZn. There is not enough zinc in the mixture to make all CuZn, nor is there enough copper to make all Cu_2Zn, so when equilibrium is obtained there is a mixture of these two constituents in such a proportion that every atom of copper and every atom of zinc is combined in one or other of these proportions. While the resulting metal is fluid each of the components is mutually dissolved in the other and we have a

homogeneous solution of CuZn in Cu_2Zn, or of Cu_2Zn in CuZn, whichever way we choose to view the matter. If now the mass can be cooled very suddenly we are able to retain the two constituents in their homogeneous solution, and we have a homogeneous solid solution as a result. If, however, the cooling is allowed to take place more slowly, then each of these metals separates out from the other, and the result is that we have a mechanical mixture of the two constituents. Here then we have in one alloy, "Muntz Metal," an exemplification of two different chemical compounds, each differing from the constituent metals, of solid solution of one of them in the other, and of a mechanical mixture of the two chemical compounds, the condition of solid solution or mechanical mixture being solely in this case due to the conditions of cooling from a high to ordinary temperatures. Actually the separation of the two constituents takes place at a temperature lower than that of solidification, so that here we have a wonderful instance of the transference of solid metallic molecules through the solid occurring during the "segregation," as it is called, of the different constituents. This is a subject which has not been fully investigated and is outside the scope of the present lecture, but some illustrations will be given to show what actually takes place, as the mechanical mixture or separation of these two metals has a distinct bearing on our subject.

The actual mixture of the two constituents is shown by the microscope. Both the compounds are of the same yellow color. When the metal is cut it appears to the eye as homogeneous, and when it is carefully polished and microscopically examined it still presents the appearance of a yellow mirror-like surface with no markings whatever on it. Let it now be lightly etched with acid, and we find definite marking on it, certain portions of the surface become darkened whilst others remain bright. What has happened is that the acid has really commenced to dissolve the surface of the CuZn portions, leaving that of the Cu_2Zn untouched. How we recognize each constituent which we see is by taking several samples of alloy varying in composition from CuZn to Cu_2Zn; treating them all in the same

way, we find that the CuZn alloy is composed entirely of the dark etching constituent, the Cu_2Zn entirely of the other, while in those alloys of intermediate composition there is always a mixture of the two substances, and the proportion of them varies just as the composition would lead one to expect.

Now returning to the question of corrosion. The etching by the acid which reveals the structure is simply a case of corrosion. Here we have two distinct metals, each by itself corrodible by the acid. They are in excellent electrical contact and are both immersed in a corrosive medium. Galvanic action ensues, the one least corrodible is preserved through the contact with its neighbor, which, however, is more vigorously atacked and eaten away by the acid. So far the matter is simple, and this explains what used to be considered to be so very mysterious, the decay of Muntz metal and somewhat similar alloys when exposed to the action of sea water. Some examples of this decay are here shown.

There were exhibited portions of a Muntz-metal condenser-tube plate and of a Muntz-metal diaphragm plate, some specimens of decayed yellow metal bolts taken from wooden ships, some brass bolts taken from a circulating-pump chamber, and a metallic air-pump valve. The latter was apparently sound, but it could be easily broken up by the hands.

It will be noticed that in each case where a decayed piece of metal has been broken the surface appears to be dull and non-metallic; where, however, the piece is filed it has a yellow metallic appearance, giving practically no indication of its actual character, although a careful comparison with a piece of sound metal similarly filed will show a distinct difference in brightness. How is this to be accounted for? If we take as an illustration a wall built with red bricks and white mortar, and supposing the bricks are stronger than the mortar, then if the wall is broken down by force the ruptured surfaces will show principally the white color of the mortar. If, however, the wall is sawn through or carefully cut right through the bricks without dragging any of them out bodily, the fracture

will show mainly the red color of the brick. It is similar in the case of the decayed Muntz metal. In the sound metal the two constituents are mixed up mechanically. One of them then becomes decayed, and then it is represented by the mortar of the illustration, the other remains practically sound and is represented by the bricks. On fracture by blow the rotten portion gives way, and we observe its color as dull brown, but on filing the metal some of the sound portions are filed through and we get the bright metallic appearance.

It may reasonably be asked why is it that in some cases the metal which decays or corrodes seems to do so in a different manner from that shown in the specimens exhibited, and disappears entirely without preserving its outward form? The explanation is probably to be found in the variation of the intensity of the corrosive influence. Where there are no extraneous electric currents to assist in the corrosion, but only the action of pure sea water, then the decay is slow and affects only the one constituent. It probably consists of a slow oxidadation of the zinc, leaving the copper in an extremely finely divided metallic state. The zinc oxide in part must get dissolved away, because the total volume of the decayed metal and oxide is only equal to that of its original bulk, but in part it surrounds the minute pieces of copper left and partially insulates them. If, however, there is, in addition to the chemical action of the water, an added electric current, the action may be sufficiently strong to oxidize not only the zinc but also the copper, and the effect of the current then falls on the other constituent, and it also begins to oxidize and decay with the result of the formation of a pit hole or the loss of original shape. If the added electric current is strong it may actually from the first overcome the protective influence of CuZn on the Cu_2Zn, and then corrosion of both constituents will take place simultaneously.

The effect of impurities in metals may be inferred to be the following. If the impurity is of a nature to be dissolved uniformly into the metal so that the impure metal is homogeneous, local currents will not be set up at all, and the impure

metal will be only subject to corrosion pure and simple, and will either tend to be preserved or to be more rapidly decayed according to the effect the impurity has. For instance take a brass which has not a duplex structure, say that used in ordinary condenser tubes, 70-30 as it is called. If there is a little tin in it, either as an impurity or intentionally added, the tin diffuses uniformly through the metal with the effect of retarding or diminishing corrosion. If, however, the impurity be a small proportion of lead, it also will be diffused or dissolved uniformly through the brass, but its presence will render the brass more corrodible.

When we come to more complex alloys, we in general get a still more complex structure than in ordinary Muntz metal. Most, if not all, of the so-called special bronzes used for propellers, etc., owe their strength to the iron they contain. They are mainly copper-zinc alloys of the Muntz-metal type, with a small proportion of iron, tin, and sometimes of other metals. The tin appears to go into solution with one or other of the constituents, and cannot be separately observed. The iron probably combines with some of the zinc, and the compound dissolves in the metal so long as its proportion does not exceed that at which the metal becomes saturated, which I believe is with about 1 per cent. iron. When, however, the iron exceeds this 1 per cent. there can always be seen in a prepared polished section of annealed metal numerous small points harder than and of different color to the rest, and these contain the excess of iron combined most probably with zinc. When etched these points are the first to be attacked and dissolved. These bronzes do not always behave in the same manner. In iron or steel vessels they generally last well. In several composite vessels with coppered bottoms the bronze propellers made for the different vessels by different makers all behaved in the same way; they became dezincified on the surface. In the first case noticed this was attributed to the vessel lying for a long time in impure river water. The propeller was filed bright and the ship was then employed in deep sea water, and it was found that the same thing occurred in the new conditions. In sub-

sequent vessels the same action took place. Now in iron or steel vessels this kind of action has scarcely ever been noticed. It was, therefore, reasonable to infer that it was due to the exceptional circumstances of the vessel being coppered. In fact, the bronze propeller and the copper sheathing immersed in sea water formed a galvanic battery.

Leaving the bronzes now, let us turn to cast iron, which is well known to suffer severely from decay in certain conditions, although in other conditions it remains good for apparently an indefinite time. Cast iron is perhaps the most complex in structure of all the metals used in every-day work, as also it is the most varied in chemical composition. Every known brand of pig seems to have a different composition depending on the ores from which it is smelted, while even from the same blast furnace working with the same coke, ore and flux, different grades of pig are produced. In all cast iron we have besides iron a considerable proportion—sometimes as much as 3.5 per cent.—of carbon, some of which may be combined with iron, forming carbide of iron, whilst the remainder exists as graphite; we always have also present in various proportions silicon, sulphur, phosphorus and manganese, all of which are recognized as ordinary constituents, and often we have other elements such as copper, arsenic, etc., as well, which are looked upon as impurities. Each of these elements, according to its amount, influences the physical properties of the iron.

When the iron is molten the whole of the elements, however they may be combined amongst themselves, must be in a liquid form uniformly diffused through the mass, and the molten cast iron is homogeneous or mainly so. On cooling, the first to solidify and to separate out is some of the carbon, which separates out in plates or partly spherical shells of graphite. If the cooling is very slow these graphite plates separate out in larger sizes than where the cooling is more rapid, and the iron is more grey and soft. Next, other parts separate out. The silicon combines with iron and manganese, forming silicides. The remainder of the carbon combines also with iron and manganese, forming carbides. The sulphur combines with some iron,

forming a brittle slag-like substance FeS, iron sulphide, which separates out in small particles throughout the mass, and finally the portion which solidifies last is a compound of iron and phosphorus. When cast iron is carefully prepared for examination by polishing, the graphite plates can be clearly seen, even with small magnification, as can also the small particles of iron or manganese sulphide, but the rest of the materials remain bright. By etching, however, and by heat, tinting the different constituents can be seen and recognized, and it is found that the phosphide of iron is always at the greatest distance from the graphite flakes, occupying, it may be said, the center of the spaces between the flakes. In this complex metal we have the very conditions for galvanic action to be set up directly a corrosive medium envelops the cast iron. The minute graphite plates are not readily oxidizable, they immediately become the minute poles of a multitude of miniature galvanic batteries. The phosphide of iron also appears to be very resistant of oxidation, so that the parts of this constituent also probably serve as poles of other minute batteries. At any rate we have every condition for a rapid oxidation of the surface.

Now let us see how the decay of cast iron proceeds. It is only too common to find iron castings which have been subject to the influence of sea water softened so that they can be cut with a knife, and in this condition they are generally said to have been converted into plumbago. By carefully preparing a section of a wasted casting at the junction of the sound and unsound portions, it can be seen that the decay first attacks the iron at its junction with the graphite plates; it then advances along the plates, and then gradually proceeds through the metallic portion surrounding the plates, leaving the phosphide compound till the last. Moreover, it is found that these phosphide portions have not only been left to the last because they have been the last attacked, but they are left intact in parts which have evidently been decayed for a long time, so that it is clear that they themselves offer a great resistance to corrosion.

So far we are considering corrosion of cast iron by itself, but it will be seen that given in addition a galvanic current in

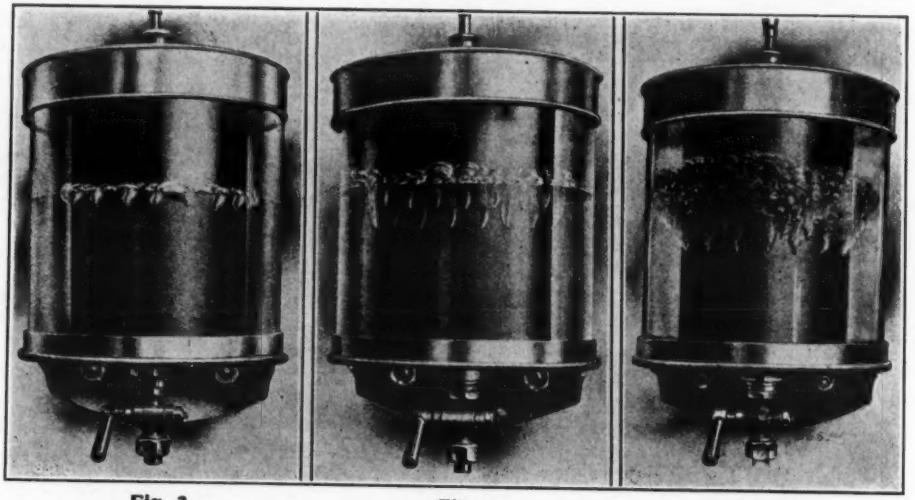


Fig. 3. Fig. 4. Fig. 5.

the right direction from an outside source we need not be surprised at the rapid rate at which corrosion will occur. Now again let us consider another point. If the corrosion is simply oxidation, then iron oxide, being practically insoluble in water, will itself form a thick coating of rust on the cast iron, which although it will probably transmit oxygen through itself, as mentioned in the earlier part of the lecture, and lead to further oxidation, it will not in any way account for the plumbago-like condition in which decayed cast iron is sometimes found. To account for this it is evident that plain oxidation is insufficient, and that there must be, in some way, other corrosive influences which permit of a solution or partial solution of the products of decay and the consequent removal of some of the iron.—"The Steamship."

THE "CONTRAFLO" SYSTEM OF CONDENSATION.

At the last spring meeting of the Institute of Naval Architects a paper was read by Mr. D. B. Morison in which reference was made to a new type of "Contraflo" condenser then being fitted in a cargo boat. Prior to the departure of this vessel on her first voyage some very interesting data were obtained, and the estimated results were fully realized. The feature in the system, apart from the particular disposition of the condensing surface, is the regulation, within limits, of the volumetric efficiency of the air pump by the control of its temperature.

It is well known that the presence of air in a condenser seriously affects the surface efficiency and lowers the vacuum, so the practical question is how it can be best dealt with. Clearly, the access of air to, and the accumulation of air in, a condenser cannot be ascribed to the action of the condenser itself. Whatever may be the reason for the air gaining access, its non-removal is at any rate directly due to insufficiency of the air pump, which insufficiency reacts on the condenser performance in such a way as to intensify the general effect. The precise manner in which air degrades condenser performance is,

perhaps, best understood by the consideration of what happens inside a condenser at work in which air is permitted to accumulate. The primary cause of the accumulation is the inability of the air pump to cope at the then existing vacuum with the quantity of air entering the system. Air being heavier than steam at all pressures obtaining inside a condenser, gravitates towards the bottom and forms an air layer, the depth of which increases until the pressure due to its weight and bulk rises to such an extent as enables the air pump to extract per unit time the same weight as gains access. Then, and only then, will equilibrium be attained, and the condenser will now be working with a greater or less proportion of its surface drowned in air, to which surface the steam cannot penetrate. The immediate result is that the effective condensing surface is reduced, the condensation rate of that portion of the surface which remains effective is increased, the temperature of condensation is raised, and the vacuum is lowered. Anything which increases the air-extracting capacity of the pump will therefore decrease the air ratio in the condenser bottom, and thereby increase the effectiveness of a greater proportion of the condensing surface, with the result of lowering the condensation temperature and raising the vacuum.

A sufficiently large pump is an obvious preventive of air accumulation; air leakage is not only variable, however, but the difficulty of its removal increases in tropical sea-water temperatures, so that a volumetric capacity of pump sufficient to deal with these conditions often involves an abnormal size. But if the temperature of the water passing through the pump can be adjusted, relatively to the temperature of the condenser, so that the condenser can be effectively rarefied at all times, it follows that the size of the air pump may be reduced to a minimum to meet normal conditions; and whenever extra duty is demanded it can be met by temperature adjustment.

It is this control of temperature which is the feature of the system as fitted in the S.S. *Gwladys*, and our illustrations show two views of the engines and condenser with the pumps removed. The size of the condenser is smaller than usual by

reason of the effective disposition of the surface and the particular arrangements for obtaining high thermal efficiency. This was fully dealt with in the paper already referred to, which we published in full on page 532 of our last volume.

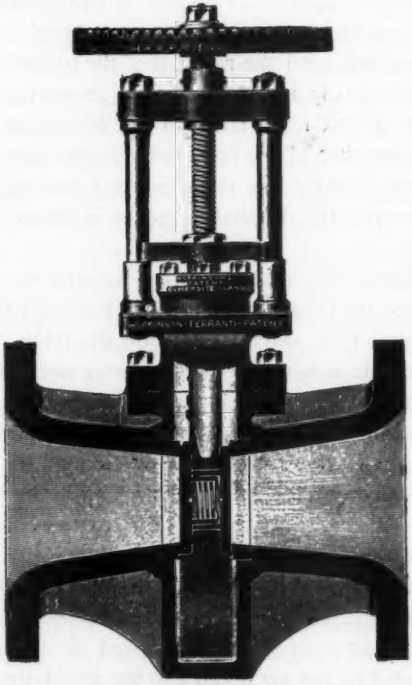
The economical vacuum for a reciprocating engine, and especially a cargo-boat engine, is, as is well known, much lower than for a turbine, and the S.S. *Gwladys* is designed to maintain 26½ inches to 27 inches all the world over. On the trials, which were under the direction of Mr. Robert Bruce, of the Contraflo Company, and the technical staff of Messrs. Richardsons, Westgarth & Co., a vacuum of 28½ inches was obtained with an unusually small quantity of circulating water, and on the vacuum being reduced about 2 inches by air leakage, it was at once raised again to the normal by regulating the temperature-control valve shown in the illustration. The flexibility so given to the air-pump capacity is thus available whenever required, with the result that the maintenance of the economical vacuum is assured under all reasonable conditions, and, what is of first importance in the economics of a cargo boat, the temperature of the feed water approaches the vacuum temperature as closely as the prevailing air leakage will permit; or, in other words, the thermal efficiency is the available maximum.

The S.S. *Gwladys* is also the first steamship in which the air gauge invented by Professor Weighton has been fitted, and its great value was fully demonstrated on the trials. At present the amount of air passing through a condenser is quite an unknown quantity, and the engineer in charge has no means of ascertaining whether the air leakage is within the capacity of the air pump, or whether a large portion of his condensing surface is air-drowned. This, in view of the degrading influence of air in a condenser, is a serious matter, but the simple apparatus, of which three illustrations are given in Figs. 3, 4 and 5, annexed, gives the engineer complete control of the position; and not only can the condenser be maintained at the highest efficiency consistent with the normal air leakage, but the power expended by the air pump and the circulating pump may

be reduced to a minimum. The apparatus has already been described by us on pages 507 and 508 of our last volume; but the illustrations now given show in a very striking manner the different effects produced by increasing quantities of air passing through the air-gauge.—"Engineering."

THE HOPKINSON-FERRANTI STOP VALVE.

Attention is being specially drawn to the Hopkinson-Ferranti stop valve. Although the valve proper is only half the diameter of the pipe, the design is such that it converts the pressure of the fluid into velocity and reconverting the velocity into pressure, thereby passes an amount of steam equal to the full carrying capacity of the pipe.



THE HOPKINSON-FERRANTI VALVE.

For this type of valve a number of special advantages are claimed, the first of these being that it halves possible leakage, because the perimeter of the valve disc and seat is one-half that of an ordinary valve. The reduction in the size of these parts also reduces the warping with high temperature, superheated steam still further reducing leakage. There is only one-eighth part the work to do in opening and closing the valve. Owing to the graded opening there is no sudden rush, as in ordinary valves. The joint making for the lid and handling of parts is estimated to be equal to that of a valve half the ordinary size. All expansion and contraction, either endwise or in a lateral direction of the pipe, is amply provided for, and therefore the valve cannot stick fast under any conditions of varying expansion or mechanical strain, as valves with wedging mechanism do.

The discs and seats are of Hopkinson's "Platnam" metal which withstands the temperature of high-pressure superheated steam. The discs are free to rotate on their axes, so that in opening and closing they slide upon their seats with a flexible pressure, which cleans the faces and prevents them being cut and scored by grit. It is further claimed that the Hopkinson-Ferranti valve is not subject to any wedging action of mechanical strains, and that when the valve is open and working the seats are sheltered from the steam flowing through the valve, while neat and uniform lagging with the pipes is facilitated.

FROM THE THAMES TO THE CLYDE.

The new shipbuilding and engineering establishment of Messrs. Yarrow & Co., at Scotstoun, on the Clyde, is now in full working order, all the building slips being occupied, and two torpedo destroyers for the Brazilian navy—the first fruits of the new works—occupying the covered-in tidal basin which is a unique feature on the river. The engineering and the boiler-making sections of the works are now complete, and the boiler-making facilities are sufficient to meet any demands en-

tailed by the projected destroyers and other classes of ships of this year's naval program. The works now give employment to considerably over 1,000 men.

Although the Yarrow shipyard is by no means one of the largest shipbuilding establishments in this country, its transfer from the Thames to the Clyde has become so universally known that it may be of interest, now that the move has been effected, to ascertain whether the expectations of the heads of the firm have been fully realized, and, if so, in what respects the wisdom of the move has been proved.

The reason which impelled the firm to leave the Thames for the Clyde was not that of making more or less profit, but of existence, because it was self-evident that the cost of production on the Thames was every day becoming more and more prohibitory, and a move was deemed to be absolutely necessary.

In estimating the relative advantages of various localities suitable for shipbuilding, the following conditions were taken into account:

1. Ample supply of labor.
2. Close proximity to the steel industry.
3. Invigorating rather than depressing climatic conditions.
4. Good educational advantages for the rising generation, and easy range of pleasant residences for staff and workmen.
5. A good measured mile for speed trials.

The locality which seemed to conform best to these conditions was Scotstoun, on the Clyde, and in comparing the cost of production there and at Poplar results have shown that it is less at the new site by 12 to 15 per cent. In London it appeared that all kinds of obstacles were put in the way of the development of the industry. The Scotstoun works are exactly the same size as the Poplar establishment; but, while the rates at Poplar were over £1,600, a year, the present rates are considerably less than half that sum. When the company desired that railway accommodation should be brought into the Poplar yard, various difficulties were placed in the way, while in Glasgow railway facilities were volunteered. Every block

upon which a vessel was built, and every necessary pile placed on the foreshore of the Thames had to be paid for, while on the Clyde the authorities facilitated the company without charge in every way, provided it did not interfere with the navigation. In fact, in Glasgow there appeared to be a general desire on the part of public bodies to encourage industries, with a view to promote the general prosperity of the city.—"The Times," London.

SHIPS.

UNITED STATES.

The Launch of Our First Dreadnought.—The launch of the *North Dakota,* the first battleship of the *Dreadnought* type to be built for the United States Navy, which took place on November 10 at the Fore River yard, Quincy, Mass., is an event of more than ordinary naval importance. Although we seem to have lagged somewhat behind the foreign navies in building ships of this type, the British having seven or eight afloat, the Germans two or three, and the Japanese two, it must be remembered that in the *South Carolina* and *Michigan* we possess two ships afloat which, though they are of only 16,000 tons displacement, each mount eight 12-inch guns, and therefore, strictly speaking, belong to the *Dreadnought* type. The launch is also significant because of the rapid work which has been done upon this, considerably the largest vessel ever built for our Navy, its keel having been laid as late as December 16, 1907, and the ship at the time of the launch being nearly sixty per cent. completed.

The remarkable record made by the shipbuilders in launching the *North Dakota* in 10¾ months from the laying of the keel is noteworthy, when it is considered that although in one or two instances abroad a battleship has been launched in slightly over eight months from the laying of the keel, still in these cases the per cent. of completion of the foreign ships was not so great as in the case of the *North Dakota,* where 9,000 tons of material, or sixty per cent. of the ship, have been worked in in the record time above mentioned, and, in addition, much of the vessel's auxiliary machinery, fittings and equipment are already finished and ready for installation, including the five

THE 20,000-TON, 21-KNOT "NORTH DAKOTA."—OUR FIRST "DREADNOUGHT."

huge turrets in which will be installed the main battery of the vessel. These turrets are at present completed and lying on the dock alongside of the berth to be occupied by the *North Dakota* when she takes her initial dip, and the installation of these housings will be at once proceeded with. It is rightly considered, therefore, that the Fore River Company have made a world record in the construction of the *North Dakota* to date; and should the same rate of production be maintained for the forty per cent. yet to produce before the vessel is ready for trial it will result in all records for battleship building being at least equaled if not surpassed.

The accompanying line drawing, which has been reproduced from the working plans of the ship, gives an excellent impression of her general appearance when viewed from abeam, and also reveals for the first time many interesting particulars of her construction. The most striking feature is the two lofty steel lattice masts, each built up of hollow-steel tubing running in reverse spirals from deck to top platform. This platform will be occupied by the officers who will have charge of fire control; and it will be their duty to record the fall of the shots, determine the range, and telephone the results down to the officers in the various gun turrets. Note should also be made of the three openwork towers, each surmounted by a large searchlight. Compared with previous battleships, there is a distinct absence of top hamper in the way of lofty flying bridges, boat cranes and superstructures. The turrets are all arranged on the longitudinal center line of the ship, consequently the whole strength of the battery can be concentrated on either broadside. The secondary battery of fourteen 5-inch guns is mounted on the gun deck. Probably in future ships these guns will be mounted one deck higher, in order to lift them clear of spray and broken water. The *North Dakota* will displace 20,000 tons on her normal draught of 26 feet 11 inches. She will be driven by Curtis turbine engines of 25,000 horsepower at a speed of 21 knots. Her coal supply when the bunkers are completely filled will be 2,500 tons.—"Scientific American."

ENGLAND.

Gas Engines in H.M.S. Rattler.—For several years past the use of internal-combustion engines for the propulsion of ships has been discussed, more, however, from the academic than the practical point of view. It is a subject that gives scope for plenty of such discussion, for even supposing any kind of agreement to be reached on the main question, there is, as yet, room for endless differences of opinion as to the relative merits of the various types of gas and oil plants for marine purposes. Most of the points raised are such as can only be definitely settled by experiments on a practical scale, and until the results of such experiments are forthcoming no amount of theorizing will bring us any nearer the final solution of the problem. Up to the present, excepting the small craft coming under the heading of motor boats, very little has been done toward the actual development of the marine internal-combustion engine. To carry out experiments on any adequate scale requires not only a firm conviction of the future of the system, and a very considerable amount of money, but also a fair prospect of finding a use, or a purchaser, for any vessel so equipped. Moreover, for the experiments to have any chance of success involves a combined knowledge of both gas-engine and marine work, which is not always to be obtained.

The rarity with which such a condition can be fulfilled accounts for the almost negligible number of attempts by the advocates of internal-combustion engines to put their ideas into practice. It is easy to point out the advantages of such engines for marine purposes, and there is always the chance, by so doing, of getting some of the credit which more properly belongs to the man who eventually attains success. Among the first who did really practical work on the subject was the late Herr Capitaine, of Frankfort, who a few years ago constructed several small tug and other boats propelled by suction-gas engines. These were designed for use on canals, but one of his boats, the *Emil Capitaine*, was tried in the Solent in 1905, and created considerable interest. She was only of 16

tons displacement and had a speed of 10 knots; she was probably the first suction-gas boat to appear in the open sea.

Following on Herr Capitaine's work, Mr. William Beardmore, of Glasgow, decided to extend the same principle to vessels of a really sea-going type, for several designs got out by Mr. W. W. May, engineer of Messrs. Beardmore's Naval Construction Works, showed that a very considerable economy might be obtained over steam-driven vessels. The producer plant and engine together weigh anything up to 25 per cent. less than the steam plant for a corresponding power, and occupy less space. Moreover, the greater efficiency of the gas plant reduces the necessary bunker capacity, and allows more room for cargo. Messrs. Beardmore thereupon commenced the construction of a 500-horsepower suction producer and marine gas engine, destined to replace the steam machinery of H.M.S. *Rattler*, an old gun-boat used as a training ship for the Royal Naval Volunteers on the Clyde. The *Rattler* is 165 feet long by 29 feet beam, and formerly contained a set of triple-expansion engines. The change to gas engines was made by the influence of the Marquis of Graham, who is the Commander of the Clyde Naval Volunteers, and who, moreover, takes a keen interest in all engineering progress. Thanks to his efforts, and the enterprize of the above-mentioned firm, not only have the Volunteers a vessel in which they make cruises away from their base, but engineers are furnished with the first example of a large marine gas engine.

The engine on the *Rattler* is of the vertical single-acting open type, with five cylinders, and a fly-wheel abaft the first two. We illustrated this engine in our issue of April 13, 1906, before it was installed in the vessel, and hope shortly to be able to give full particulars of its construction. The ordinary four-stroke cycle is used, each cylinder being 20 inches in diameter, with a stroke of 24 inches, and developing 100 brake horsepower. The crank shaft runs at 120 revolutions per minute. The pistons are not water-cooled, and the open framing renders the connecting rods and cranks fully visible from either side. The design of the framing strikes one as exceptionally good.

It is constructed entirely of steel plates and angles, the plating being curved round to form the crank race, and continuing upwards on each side to support the cylinders. These latter, with their heads, are the only important details made in cast iron. The engine when running is perfectly steady, in spite of the apparent and actual lightness of the framing.

The valves are situated vertically in the cylinder-heads, the inlet valves in a row on one side of the engine, and the exhaust valves on the other. Each set is worked from a cam shaft running alongside the lower end of the cylinders, the cam shafts being driven by inclined bevel-geared lay shafts from the aft end of the crank shaft. The valves are all water-cooled, connections being made by flexible rubber tubes to a sort of cross-head on the stem. Low-tension make-and-break ignition is employed, each cylinder having its own magneto. Messrs. Beardmore consider this the most satisfactory for marine work on account of the absence of high-tension leads, and the apparatus on H.M.S. *Rattler* has justified this view by working faultlessly for the twelve months or more during which she has been in commission. . Forced lubrication is used for the cylinders, but not elsewhere. Any cylinder can be shut off independently of the others, so that its valves, ignition, etc., can be examined, if necessary, while the rest of the cylinders are working.

Starting is effected by means of gas stored in reservoirs at a pressure of 95 pounds per square inch. This is turned on, and the engine moved by a bar. The compression-relief cams being in action, there is no compression in the cylinder, and the momentary automatic depression of a special starting valve allows the gas to enter immediately before the firing point. A baffle device of numerous thin plates prevents any possibility of a back-fire in the gas pipe. Moreover, the mixture cannot be fired until the admission valve is closed. As soon as the engine starts, the starting-valve gear and the relief-compression gear are, of course, put out of action. When, by the courtesy of the Marquis of Graham and the constructors of the machinery, we had the opportunity of having a trip in the *Rattler,* the

engines went away practically instantaneously—at the second stroke of the bar, in fact—and we understand they may be relied upon to do so. They are reversed by means of an hydraulic clutch and epicyclic gear. A description of the reversing gear would be unintelligible without drawings, which we hope to give on a future occasion. The principle, however, is well understood by engineers.

The suction producer consists of a cylindrical steel casing lined with fire-brick, and uses anthracite coal, which is admitted by means of a feeding hopper in the water-cooled cover. The fuel rests on trough-shaped bars arranged radially, with their inner ends resting on a water-cooled tube. The steam used by the producer is supplied by "boilers" arranged one on each exhaust branch of the engine. These are casings containing a nest of tubes, around which the exhaust gases pass. Besides supplying the necessary steam, the "boilers" effectively silence the exhaust. After leaving the producer the gas passes upwards through the cooling tower, which is simply a vertical pipe, down which water is sprayed. This cools the gas and removes dust and grit. Thence it goes to the centrifugal drier, in which a high-speed fan throws out all water, etc., which is drained away to a water seal. From the fan it passes to the cleaner, which is a square box filled with a labyrinth of closely-packed perforated plates, upon which settle any dirt or water that may possibly have escaped the action of the drier. Thence the gas goes to the engine. Very little useful space is occupied by the washing, drying and cleaning apparatus. Other auxiliary apparatus includes a small steam-driven compressor for filling the starting reservoirs. For this and other purposes on board for which steam is useful a vertical donkey boiler is installed.

From the brief description we have given it will be seen that the plant has been most carefully designed for the purpose in view, besides being of more than ordinary interest on account of its size and novelty. It may, or may not, be along the final lines which large marine internal-combustion plant may take; but it marks the first important step in the development of such

plant. On the occasion of our visit already referred to it ran perfectly in every way, and with no noticeable noise. Externally the engine may appear more complicated than the steam engine; but all that there is can be seen, and anything that is lost in the engine room is more than made up in the "stokehold." The smallness of the space occupied, and the slightness of the attention required were very noticeable, while the certainty of the absence of many of the troubles inherent in boiler plant is no small consideration at sea. Producers, no doubt, have their faults; but they are at their best when working under a steady load, such as marine practice involves.—"Engineering."

The Machinery of H.M. Battleships Agamemnon and Lord Nelson.—We return to the subject of these important battleships in order to describe the main engines. In our issue of September 4, on the two-page plate, No. XXI., we gave a front and end elevation and a plan of one set of the twin engines, and on the two-page plate this week we reproduce general drawings illustrative of the arrangement of the propelling engines and auxiliaries in the engine room.

The propelling machinery consists of two sets of four-cylinder triple-expansion engines, arranged in separate watertight compartments, with a longitudinal bulkhead (Fig. 9). These compartments are entirely independent of each other, there being no watertight door fitted in the longitudinal bulkhead.

The engines were designed to develop collectively 16,750 indicated horsepower at 120 revolutions per minute, with a boiler pressure of 275 pounds per square inch, and on the eight-hours' trial gave 17,285 indicated horsepower at 130 revolutions, with a pressure of 262 pounds. The diameters of the cylinders are: High pressure, 32¾ inches; intermediate-pressure, 52¾ inches; and each low-pressure, 60 inches, all having a stroke of 48 inches. All the cylinders are fitted with liners, those for the high-pressure and intermediate-pressure being of solid forged steel, and those for the low-pressure of cast iron. All the cylinders are steam-jacketed. The valves of the high-pressure and intermediate-pressure cylinders are of the piston

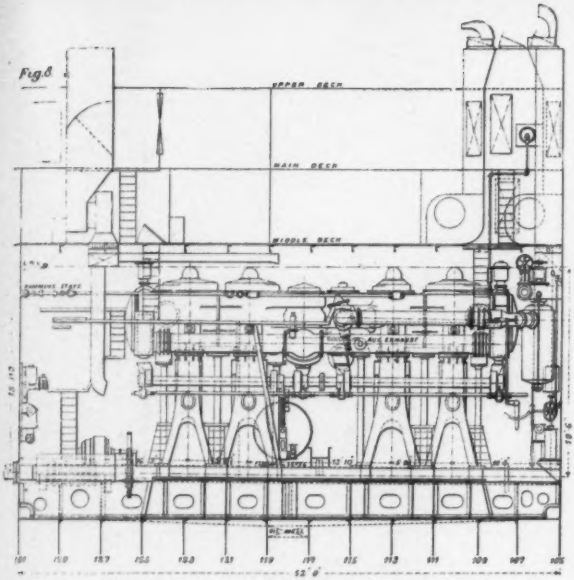
type, and those for the low-pressure flat double-ported slide valves, with relief-rings fitted to the back. The valve gear is of the double-link motion type. The reversing gear is of the all-round type, and independent links, arranged with adjusting screws to regulate the cut-off in each cylinder, are fitted.

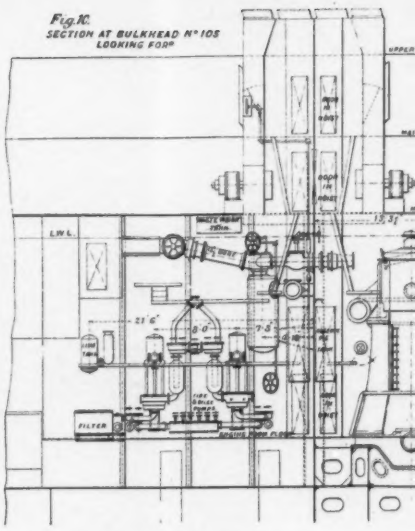
The bed plate, pistons and cylinder covers are made of cast steel, the front columns of forged steel, and the back columns of cast iron, of rectangular form and substantial section.

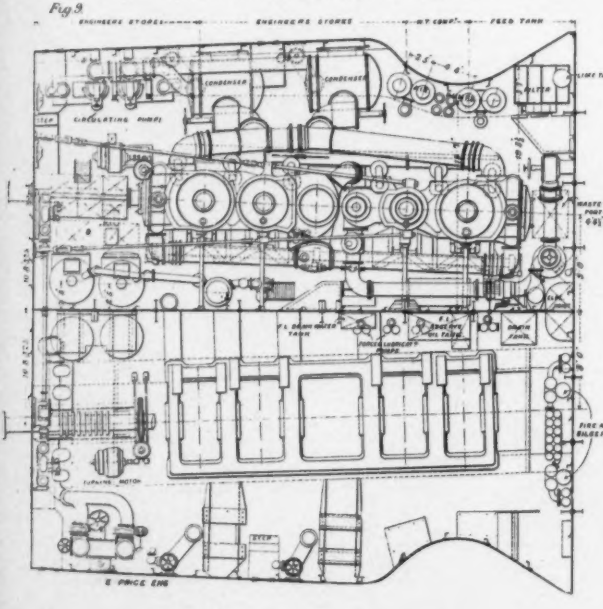
The shafting is hollow throughout, and for the *Agamemnon* engines was supplied by Messrs. W. Beardmore & Co., Limited. The diameter of the crank shaft is 17¼ inches, with 8¾-inch hole; the crank pin is 18¾ inches in diameter, with 10-inch hole, the length of the pins for the high-pressure and intermediate-pressure cranks being 21½ inches, and those for the low-pressure 13½ inches. The angles of cranks are arranged to balance the moving parts and give an efficient turning moment. The propellers are of manganese-bronze, 15 feet in diameter, and 19 feet pitch; number of blades, 4; and surface, 90 square feet.

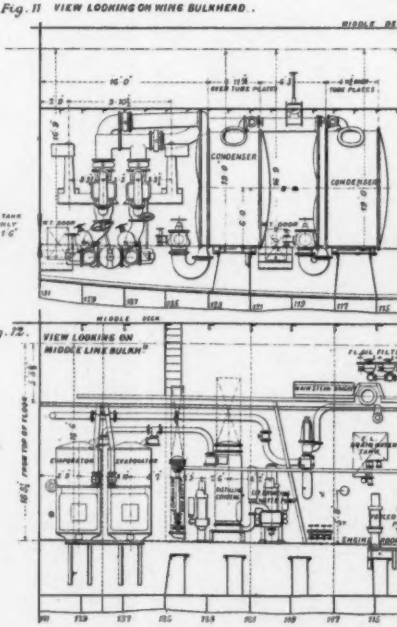
The engines are fitted with forced lubrication, and the oil is supplied to the main bearings, crank-pit bearings, etc. Three pumps are fitted in each engine room. One pump is arranged to draw the oil from the save-all and to deliver it through strainers into the reserve oil tank, and also is connected to the ship's oil tanks to replenish the reserve tank in case of loss. One pump is fitted to draw from the reserve tank and deliver to the various bearings. The arrangements are such that the supply of oil can be regulated to each main bearing and crank pin independently. The third pump is arranged to either draw water from the save-all, to draw oil from the save-all, and deliver through the strainer to the reserve oil tank, or to draw oil from the reserve tank and to deliver to the various bearings, and therefore can be used for duty for either of the other pumps. Oiltight casings are fitted to incase all the principal moving parts, and these are carried to sufficient height on the engines to prevent spray escaping into the engine room.

Special bearing rings and springs are fitted at each end of









GENERAL ARRANGEMENT OF PROPELLING ENGINES AND AUXILIARY

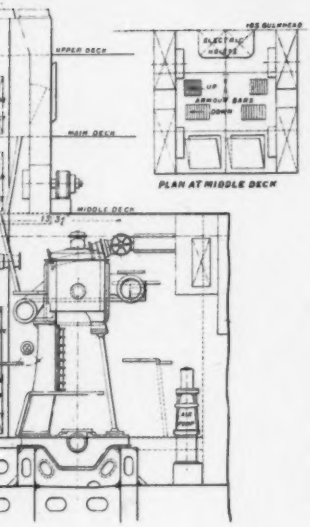
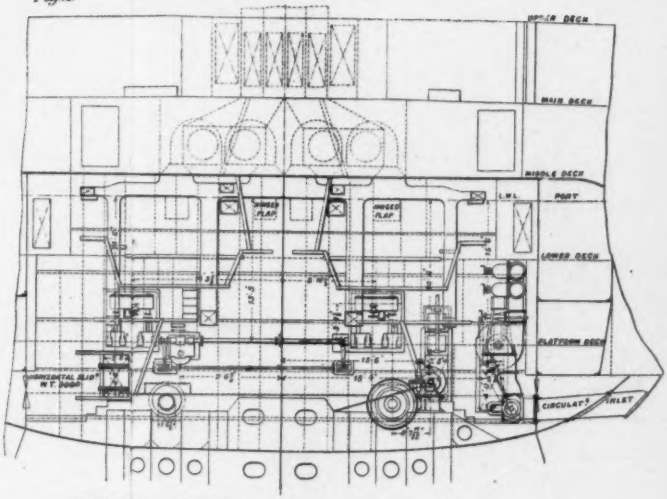


Fig 13. VIEW LOOKING ON PORT SIDE OF BULKHEAD 191.



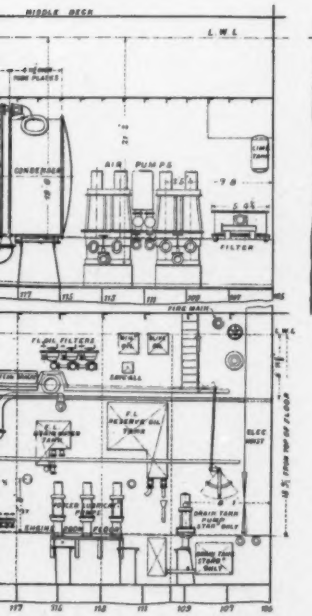
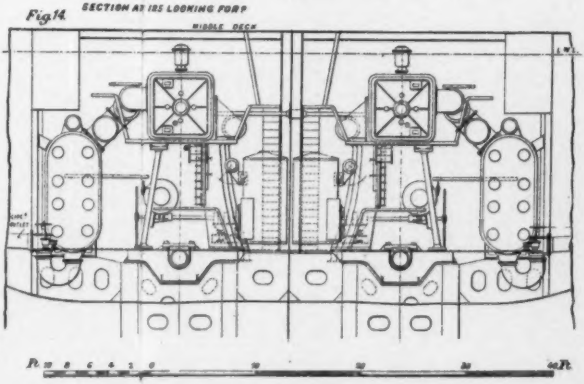
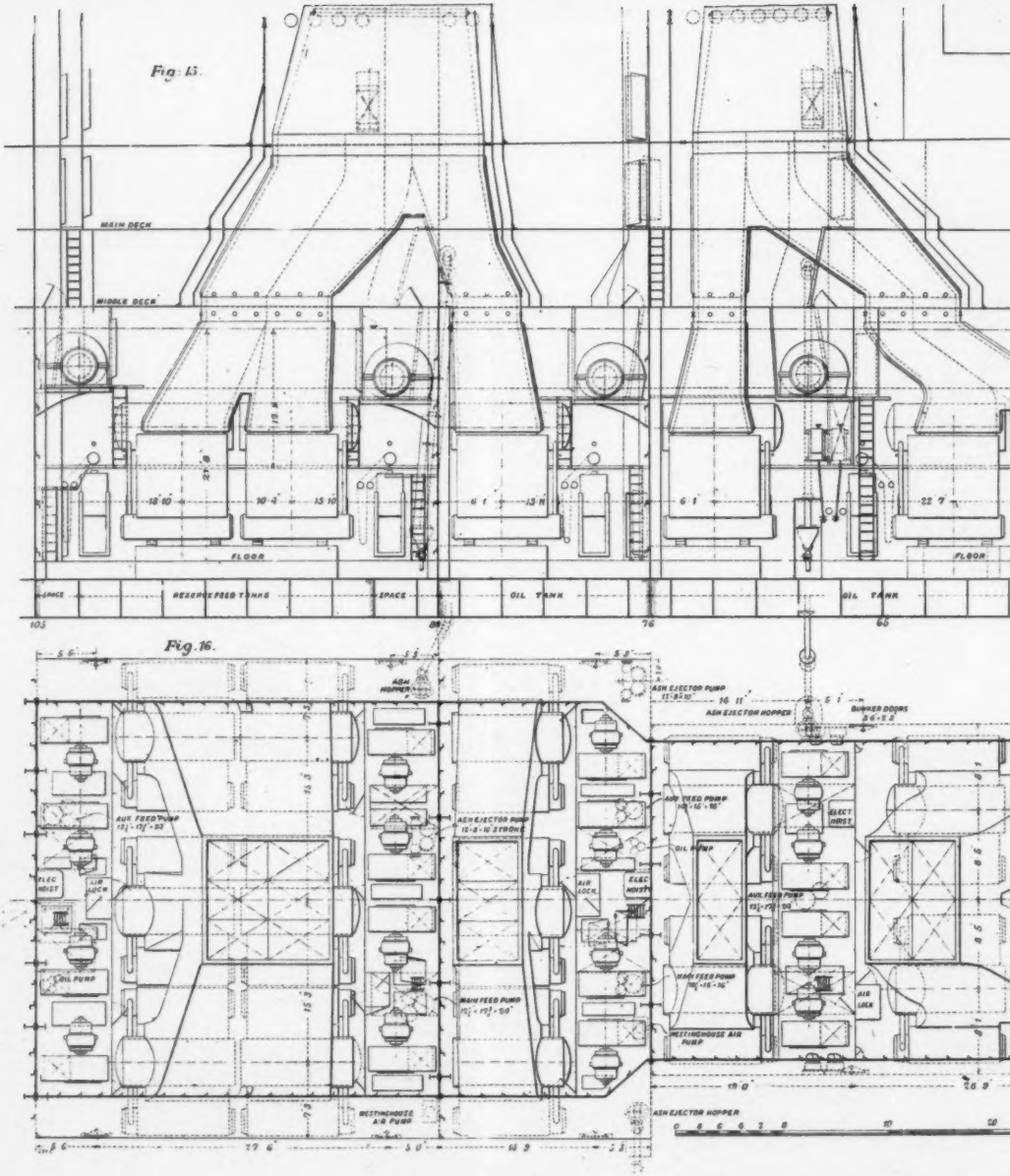


Fig 14. SECTION AT 105 LOOKING FORE



ENGINES (Twin-Screw Four-Cylinder Triple-Expansion):—		
Diameter of H.-P. Cylinder	... ...	92½ In.
Diameter of I.-P. Cylinder	... ...	52½ In.
Diameter of Each L.-P. Cylinder	...	60 In.
Stroke		48 In.
BOILERS:—		
Total Heating Surface ...	... ...	50,205 Sq. Ft
Total Grate Area ..	... ...	848 Sq. Ft.
Working Pressure ..	...	275 Lb. per Sq. In
FULL-POWER TRIAL RESULTS ("Agamemnon"):—		
Revolutions	... ...	130 per Min.
Indicated Horse-Power ...	.. ...	17,235 H.-P.
Speed of Ship	.. ...	18.736 Knots.

IARY MACHINERY IN H. M. SS. *AGAMEMNON* AND *LORD NELSON.*



GENERAL ARRANGEMENT OF BOILERS IN H.

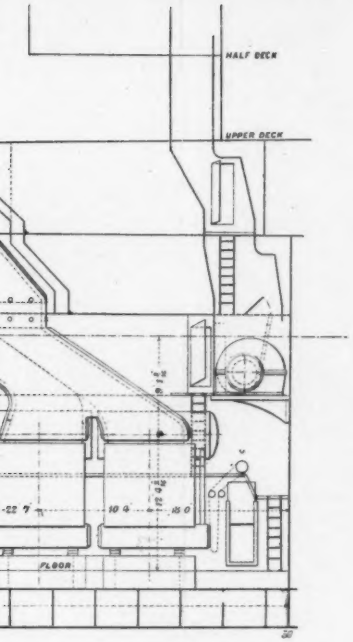
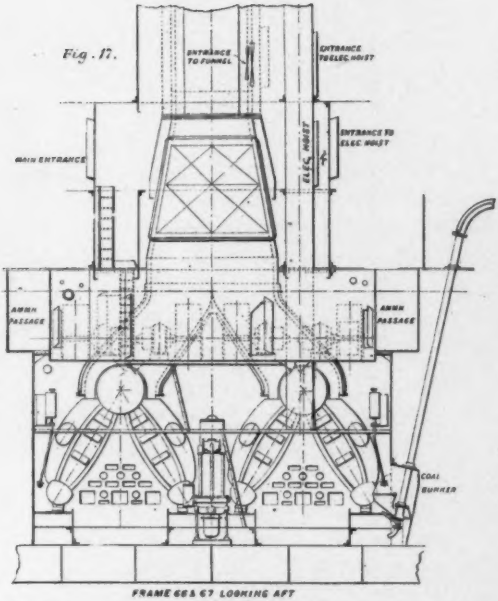
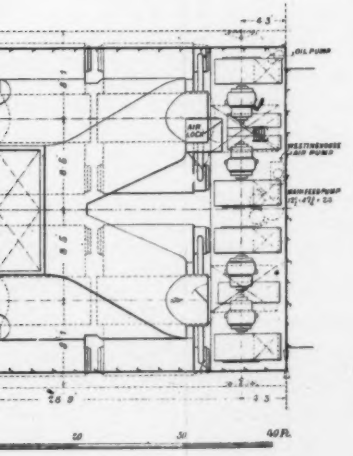


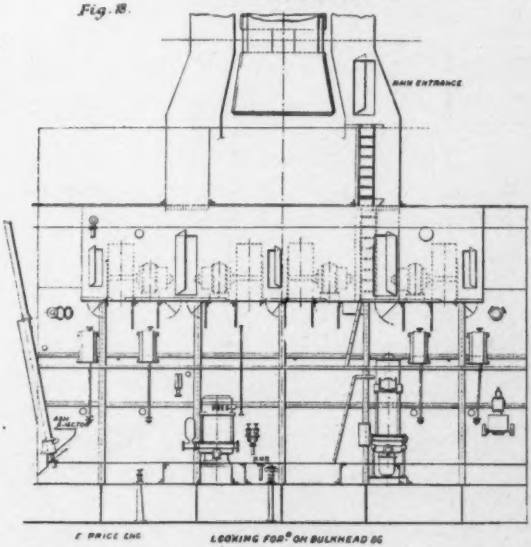
Fig. 17.



FRAME 66 & 67 LOOKING AFT

Fig. 18.





LOOKING FOR^{D} ON BULKHEAD 66

IN H. M. BATTLESHIP *AGAMEMNON.*

the main bearing, to prevent excessive leakage of oil. The thrust block is arranged so that the collars are immersed in oil, and the shoes are made hollow and fitted with water-cooling arrangements.

Two condensers are fitted in each engine room, each having a cooling surface of 5,026 square feet. Two circulating pumps, by Messrs. W. H. Allen, Sons & Co., Limited, are fitted in each engine room, and are arranged so that each pump can supply either condenser.

Two twin air pumps, by Messrs. G. & J. Weir, Limited, are fitted, and draw from the condensers and deliver through the grease-extractor into the feed tanks. No auxiliary condensers are fitted in the ship. The auxiliary exhaust system is led to either the main condenser, low-pressure cylinder receiver or to the evaporator coils.

The distilling plant, by Messrs. J. Kirkaldy, Limited, consists of two evaporators and one distilling condenser in each engine room, and the total output of plant in the ship is 180 tons per twenty-four hours, the distilling condensers being capable of condensing all the steam made by the evaporators.

Fire and bilge pump and drain-tank pumps, by Messrs. Henry Watson & Sons, are also fitted. The engine-room arrangements are identical in both ships.

We complete our illustrations of these two important battleships by giving on Plate XXVI. the general arrangement of the boilers in the *Agamemnon,* the machinery of which was constructed by Messrs. R. & W. Hawthorn, Leslie & Co., of Newcastle-on-Tyne. The boilers in this case were of the Yarrow type; in the *Lord Nelson* they were of the Babcock & Wilcox type, but, with this exception, the installations are not dissimilar. The total heating surface is 50,265 square feet, and grate surface of 848 square feet.

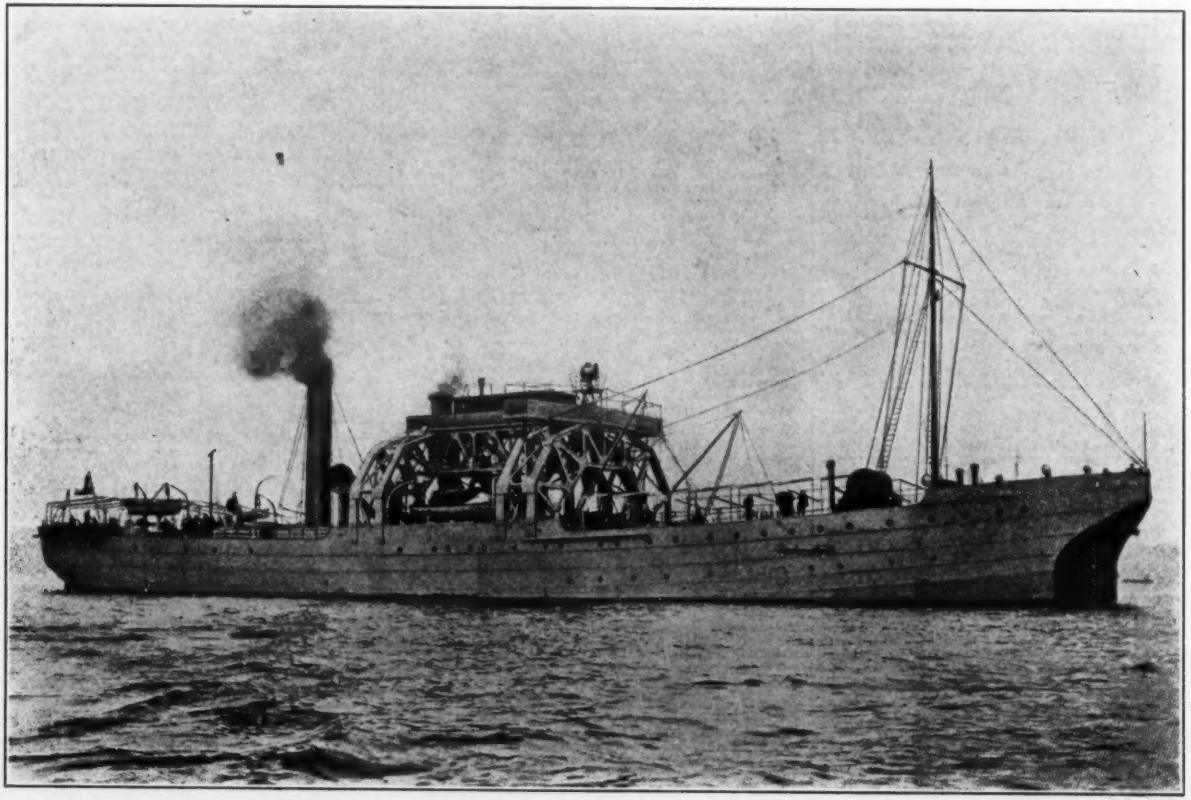
Twenty electrically-driven Sirocco fans by Messrs. W. H. Allen, Son & Co. are fitted, and three-fourths of these are capable of supplying the air required when the main machinery is developing full power. One main and one auxiliary feed pump, by Messrs. G. & J. Weir, Limited, is fitted in each boiler

room. Two ash-ejector pumps, by Messrs. Clarke, Chapman & Co., are fitted, and three ejectors, by Mr. F. J. Trewent, one ejector in each boiler room. One air-compressor engine, by the Westinghouse Brake Company, is used in each boiler room, and is used for sweeping the boiler tubes.

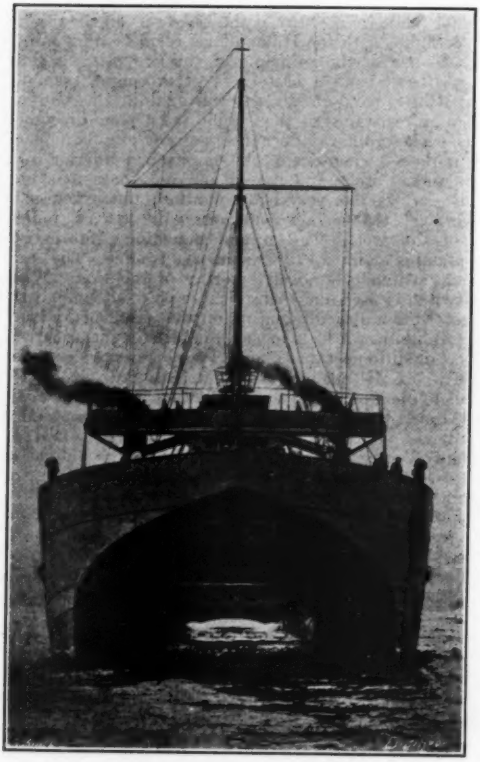
The three steam-driven electric engines and dynamos are of the Brotherhood-Laurence-Scott combination. Two oil-driven dynamos are supplied by Messrs. R. Hornsby & Sons, the dynamos being of Laurence-Scott manufacture. The steam and *oil-driven* dynamos are fitted to run parallel. Two sets of vertical steering engines are fitted by Messrs. Napier Brothers, Limited, and are arranged on the aft bulkhead in the engine room; a clutch is fitted to the shafting between the engines, so that either engine can work the gear at the rudder head.

GERMANY.

German Naval Dockship Vulcan.—The dockship *Vulkan* has recently been placed in commission in the German navy. It has been built in accordance with the plans of the Imperial naval constructor, Ph. von Klitzing, of Kiel, by the Howaldtswerke at that place. The distinguishing feature of the *Vulkan* is its peculiar form. The vessel itself consists primarily of two hulls, both resembling ships linked together fore and aft above the water-line by steel girders made up of angles and plates. This linking or joining together is done in such a manner that a torpedo boat or submarine riding at the surface can steam between the two hulls. When the small craft is in this position tackles and crane hooks can be lowered from the dockship, and the little vessel can be lifted out of the water and docked. After that, from both of the inner sides of the dockship, beams are swung under the smaller vessel, so as to form a platform on which she may rest. The beams are fastened by hinges to the inner side of the dockship. That is to say, they are fastened to the inner side of one of the hulls, and are pulled up against the inner side of the other hull as far as it is advisable to raise the docked boat. These beams



THE GERMAN DOCK SHIP "VULKAN."



DOCKSHIP "VULKAN."

play no actual part in the raising of a vessel, that action being performed wholly by the cranes and tackles on the dockship. The center of the dockship is free, and the submarine or torpedo boat may be raised as far out of the water as desired. The hoisting or lifting apparatus is arranged on two double portals or bridges built up of lattice girders, the bases of which girders rest on the decks of the two hulls. These girders also serve as a rigid connection between the two hulls.

The means of propulsion of the vessel are interesting, for neither reciprocating engines nor turbines, but electric motors, are employed for driving the two propeller shafts. Current is delivered to the motors by two independent turbine generator sets. If the vessel is to steam slowly one generator set only is run. All the switches and controlling mechanism for the entire machinery are operated from the bridge, so that no intercommunication between the commanding officer and the engine room is necessary. Steam is generated in four Mehlhorn water-tube boilers.

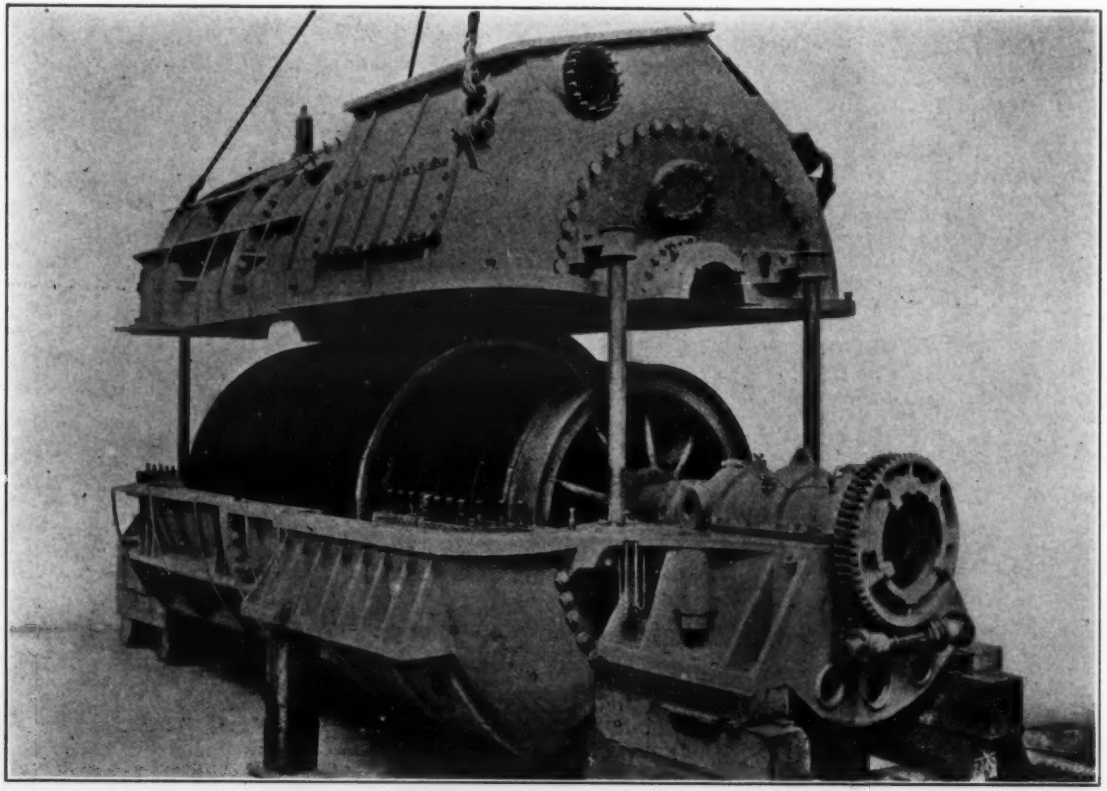
One of the purposes for which the vessel is destined is to serve in salvage operations for sunken submarines, the necessity for such a salvage ship having become more and more apparent as the development of submarine practice has progressed. The trials of the ship have, so we gather, been very satisfactory—so much so, in fact, that a second and larger ship of the same type is under consideration for the other great German naval bases.

Views of the *Vulkan* are given, one of these showing the vessel just after she left the launching ways. These show excellently the form of the vessel.—"Engineering."

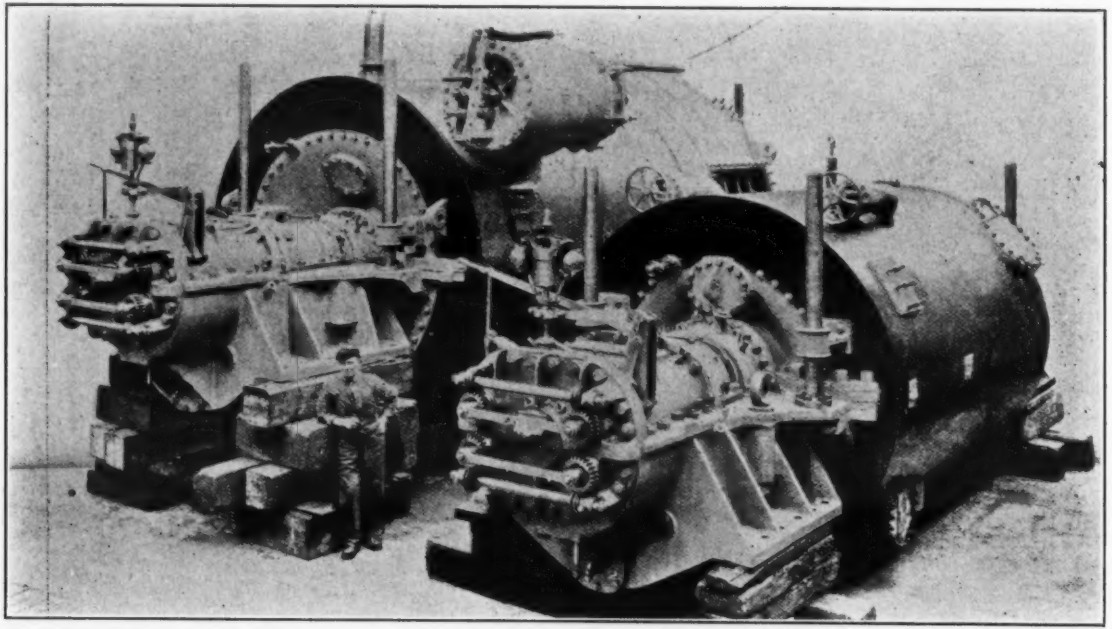
MERCHANT SHIPS.

Triple-Screw Turbine-Driven Pacific Liner Tenyo Maru.—The completion of the new Pacific liner *Tenyo Maru*, the first of the three sister ships for the Toyo Kisen Kaisha (Oriental Steamship Company of Japan), was undoubtedly an event of first importance in the shipbuilding and engineering industry on the Pacific Coast, as the vessel is not only the largest ship yet built in the East, but is the first steamer in Pacific waters fitted with turbines, and the Mitsu-Bishi Dockyard and Engine Works, who designed, built, engined and entirely equipped the vessel, are to be congratulated on the results of the work. In this ship we have practically the highest development of shipbuilding and engineering work, and modern examples of Eastern decorative work.

The Design.—It was in the middle of July, 1905, when the orders for two new Pacific liners were placed with the Mitsu-Bishi Works to the owners' design. The builders submitted alternative designs, proposing to adopt their own design on the ground that in this case the hull would be lighter by 200 tons. Turbines were suggested instead of reciprocating engines. Both proposals met with the approval of the owners, who showed the same measure of courage as did the Mitsu-Bishi Works, the licensees for manufacturing Parsons' turbines in the East. It is true that steam turbine machinery had at this time been fitted on a number of steamers in Europe, but they were of comparatively small displacement; the larger ships (since completed) with turbines were not then in service. As Mr. H. Maruta, the general manager of the Mitsu-Bishi Works, put it at the luncheon after the launching of the vessel on September 14, 1907, no one could help admiring the foresight, enterprize and courage which characterized the decision



One Low-Pressure Ahead and One Astern Turbine of the "Tenyo Maru."



THE HIGH PRESSURE AND ONE OF THE LOW-PRESSURE TURBINES OF THE "TENYO MARU."

Fig.1.

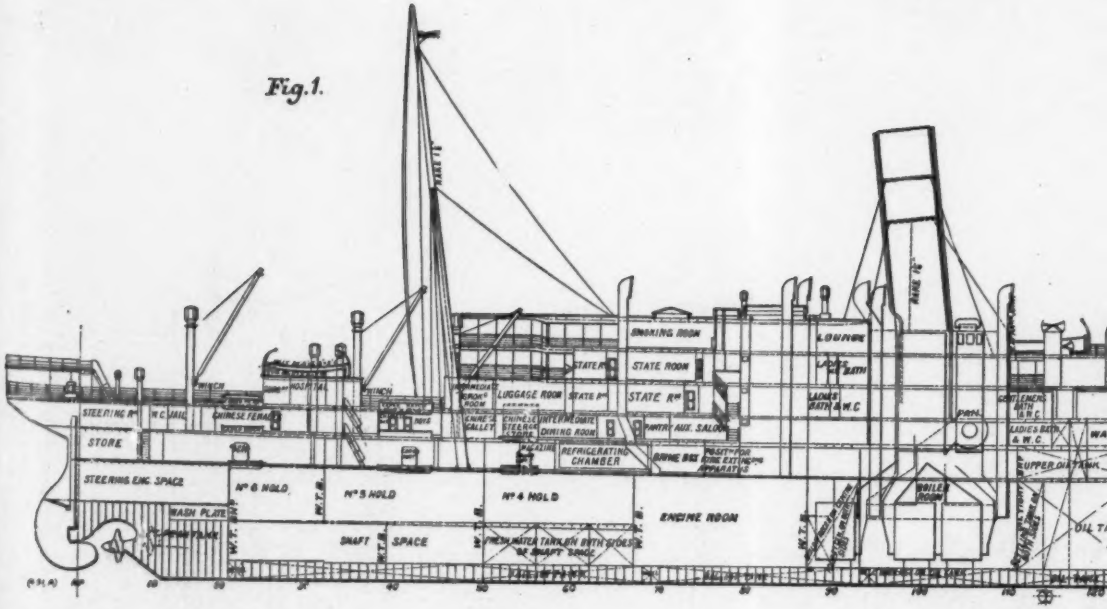
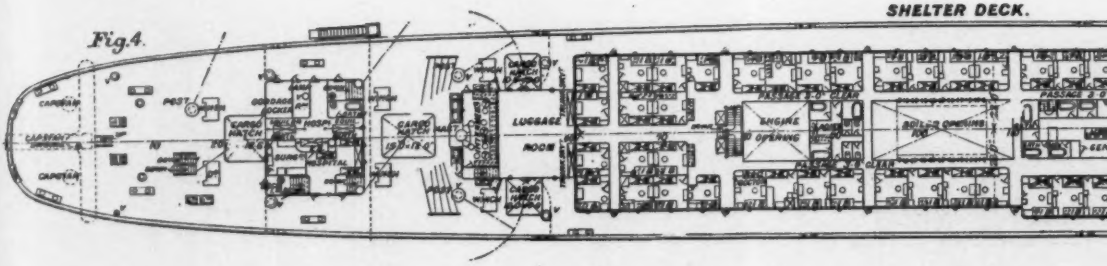
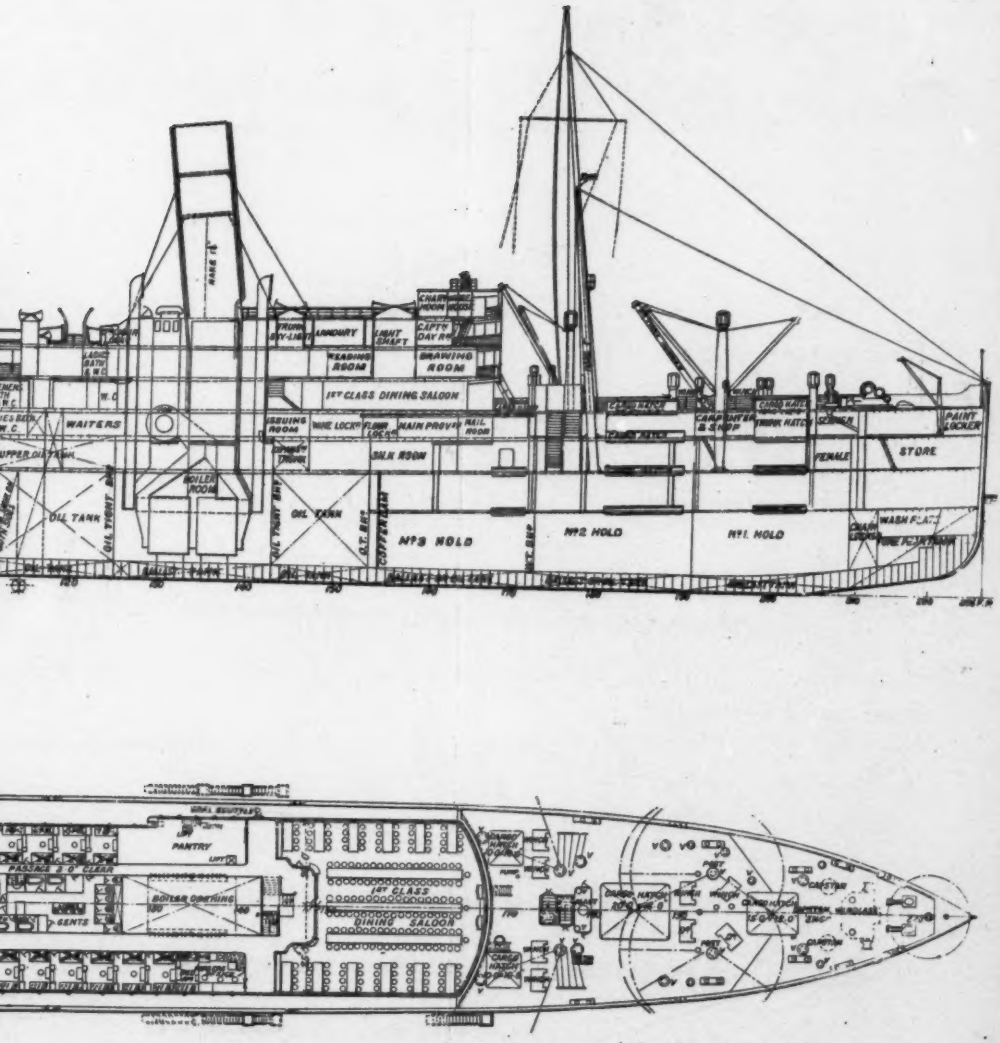


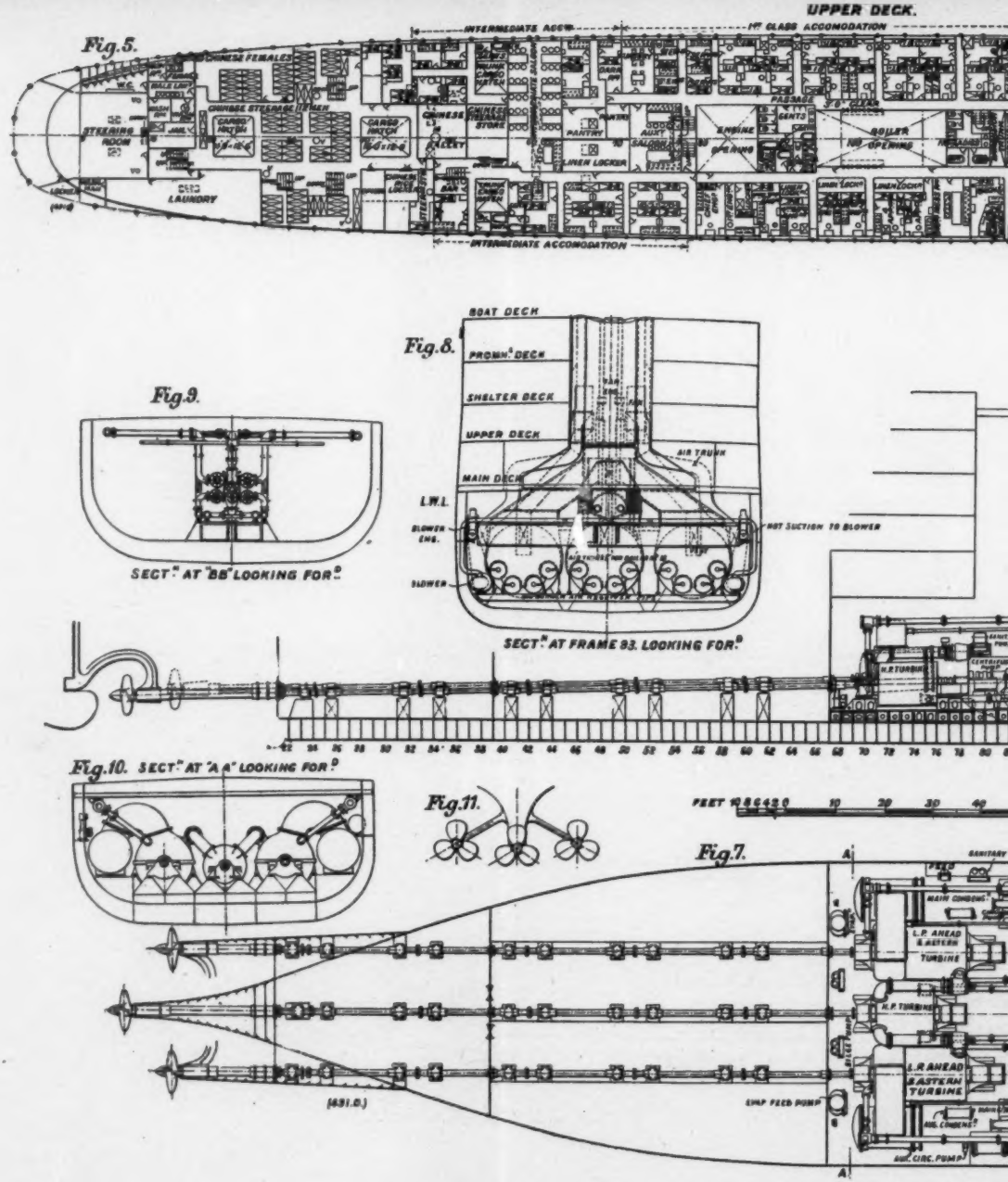
Fig.4.



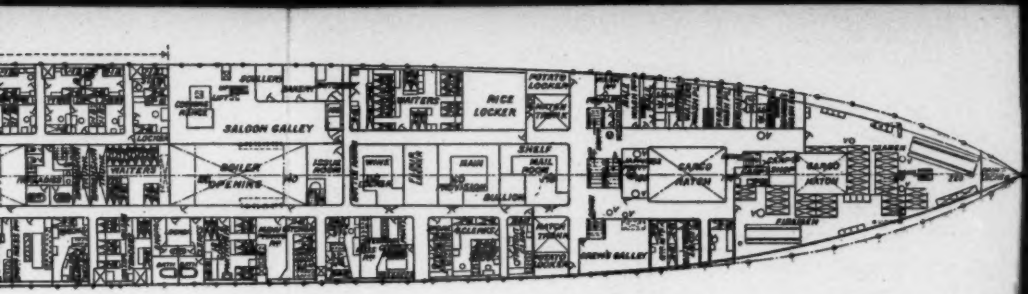
THE TURBINE-DRIVEN PACIFIC LINER *TENYO MA*



O MARU, FOR THE TOYO KISEN KAISHA.



THE TURBINE-DRIVEN PACIFIC LINER *TENYO M*



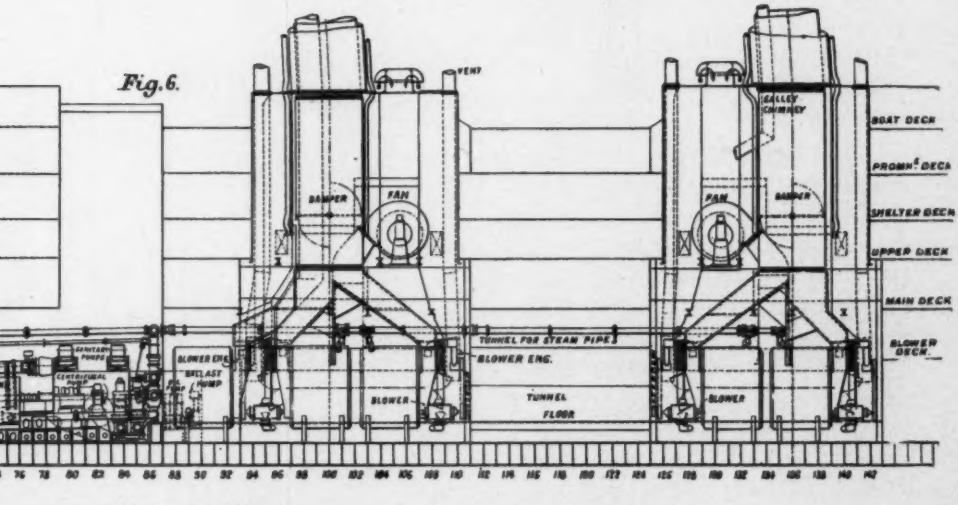
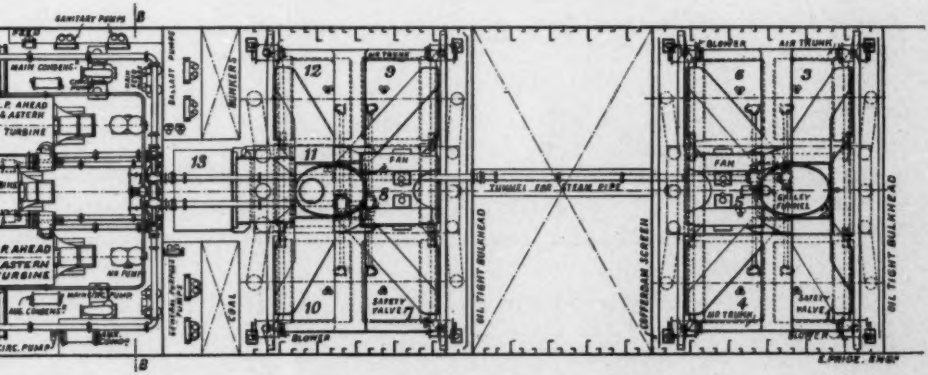


Fig. 6.

Scale for Figs. 6 to 11.



ENYO MARU, FOR THE TOYO KISEN KAISHA.

of the Toyo Kisen Kaisha in adopting the turbines in the new Pacific liners—a decision since proved to be fully justified by the results obtained in Europe. The decorative designs of the public rooms were entirely in the hands of Professor Tsukamoto, of the Imperial University, Tokio, by the owner's appointment.

Dimensions.—The principal dimensions of the vessel are: Length between perpendiculars, 550 feet; length over all, 570 feet 9 inches; breadth molded, 63 feet; depth molded, 38 feet 6 inches; loaded draught, 31 feet 8 inches; displacement at this draught, 21,650 tons; height from keel to roof of wheel house, 84 feet; height from keel to top of masts, 167 feet; height from keel to top of funnels, 129 feet; gross register tonnage, 13,454 tons; number of first-class passengers carried, 261; number of second-class passengers carried, 47; number of third-class passengers carried, 618; number of officers, engineers and crew carried, 250.

The Building of the Hull.—The first keel plate of the *Tenyo Maru* was laid on November 17, 1905, and she was launched on September 14, 1907. She proceeded on her official trials on February 19, 1908, so that she was completed within twenty-eight months. Had she been fitted with ordinary reciprocating engines this time would have been much shorter, for, owing to the equipment of new plant, etc., in connection with turbine manufacture, the machinery took longer to complete than would otherwise have been the case.

In the construction of the vessel 7,500 tons of steel were required. In many cases the plates have quadruple riveting. The flat-plate keel is fitted with a flat keel 2½ inches thick, scarfed, so that a flush surface is obtained for the entire length of the vessel. This is a great convenience in connection with dry-docking of the vessel. The flat-plate keel is 48 inches broad and $\frac{21}{20}$ inch in thickness, and the center girder plate is 53 inches deep and $\frac{13}{20}$ inch in thickness, and is secured by angles 5 inches by 5 inches by $\frac{13}{20}$ inch to the flat-plate keel, and 4 inches by 4 inches by $\frac{12}{20}$ inch to the inner-bottom plating. This construction is continued for the whole length of the ship, although the

thickness of the plates and bars is reduced at the forward and after ends.

The inner bottom of the ship is 50 feet wide at the central part, tapering towards the bow and stern to take the form of the ship. This structure is built up of floor plates at right angles to the center girder, of a depth of 53 inches, and extending nearly to the turn of the bilge. Fitted intercostal with these, there are on each side of the center girder three longitudinals, secured by angles and forming, with the plating, the double-bottom structure of the ship. This double bottom is used for carrying water ballast and oil fuel, and to give access to all parts. Incidentally it lightens the structure; holes have been formed in both the floor plates and intercostal girders. The fourth girder from the center line, known as the margin plate, is continuous fore and aft.

The side framing above the double bottom is of channel section 9 inches deep for the greater part of the length of the vessel. The spacing of the framing in the center part of the ship is 30 inches and at the bow and stern, where heavy angles take the place of the channels, it is diminished to 27 inches. These angles have reverse angle bars near the edge of the transverse flange. Each fourth frame in the machinery and boiler compartments, and each sixth frame in the aft hold, are of web section, built up of plates over ½ inch in thickness and 30 inches to 24 inches deep, with strong angles on the inner edge, and riveted to the shell of the ship. The web frames extend vertically to the upper deck. The web frames were built in the framing yard and were fitted there, with all connections hydraulically riveted, and in this state were subsequently moved to the building berth.

The main framing thus described extends to the shelter deck. The deck above this, forming the promenade deck for passengers, with central deck houses for cabins and public rooms, is supported by heavy tee-standards 6 inches deep and 5 feet apart. The boat deck, above the promenade deck, is supported by 2½-inch round-iron stanchions, also 5 feet apart.

The shell plating is for the most part $\frac{16-15}{20}$ inches in thickness and generally of 5 feet width of strake; it is almost entirely quadruple riveted.

The three topside strakes of the plating of the hull, which are of $\frac{22}{20}$ inch, $\frac{20}{20}$ inch and $\frac{20}{20}$ inch, respectively, and reduced at the ends, are double strapped and quadruple riveted; and the next two strakes, which are $\frac{18}{20}$ inch in thickness reduced at the ends, are quadruple riveted. The butts of the keel plates are double strapped and treble riveted.

Wherever possible hydraulic riveting was resorted to, and even before the rivets were put in the plates and angles were forced and held together by hydraulic power, so that the temporary bolts and nuts should bring the surfaces as closely together as possible before riveting. In this way there was absolutely no possibility of yielding when the rivets were put in. The work done by hydraulic power includes the landing and doubling of the shelter-deck sheer strake, the strake below, and the shelter-deck stringer plates, bars, keel plates, and slab-keel plates. The rivets in the shell and tank top plating vary from ¾ inch to 1⅛ inches in diameter, spaced on an average 3½ to 4 diameters apart. In the bulkheads the sizes generally are ¾ inch in diameter, spaced 4½ to 7 diameters apart; the deck rivets are ¾ inch, spaced generally 4 to 4½ diameters apart.

The inner bottom plating ranges from 5 feet 9 inches to 6 feet in breadth of strake, and ½ inch in thickness, reduced toward bow and stern. It is, however, thicker in the boiler and machinery spaces, where further strength is imparted to the structure by a greater number of longitudinals, built intercostally with the floor plates. This inner plating is lapped and treble riveted, and joggled and double riveted at the edges.

There are twelve bulkheads, of which four are oiltight for oil-fuel bunkers, built of $\frac{8}{20}$ inch to $\frac{7}{20}$ inch plating with 7-inch angle stiffeners, extending to the lower deck and spaced 30 inches apart. These are connected by large brackets to the tank top plating and to the lower deck. The horizontal stiffeners are 9½-inch bulb angles spaced 48 inches apart. Above

the lower deck—*i. e.*, the 'tween-deck bulkheads—the stiffeners are $5\frac{1}{2}$ inch angles. The oiltight bulkheads are built of $\frac{19}{20}$ inch to $\frac{8}{20}$-inch plating with $9\frac{1}{2}$-inch bulb-angle vertical stiffeners, spaced 30 inches apart, and $9\frac{1}{2}$-inch bulb-angle horizontal stiffeners, spaced 48 inches apart. The bulkhead at the aft end of the machinery space, the bulkhead to the shaft tunnel, that between the machinery and the aft boiler room, and that between the aft and fore boiler rooms, are each fitted with watertight doors on the "long-arm" system. In the aft holds the level of the lower-deck flat is lowered to form the tunnels for the propeller shafts, and has a longitudinal bulkhead near the center line, and also one against the side of the ship on each side, forming fresh-water tanks.

The deck beams are of deep channels throughout, and are connected to the framing by knee brackets, and supported vertically and tied together by solid circular pillars and double channel-bar pillars, the latter being used for wide-spaced arrangement.

The deck plating is $\frac{11}{20}$ inch to $\frac{8}{20}$ inch in thickness, but is heavier where required, principally in the stringers or outside strakes of the deck plating, which are $\frac{29}{20}$ inch to $\frac{11}{20}$ inch, reduced at the ends, with extensive doubling in the main structural decks. The laps are joggled and single riveted. The butts are also joggled and treble riveted generally.

At the corners of the hatchways, engine and boiler casing openings, there are heavy plate doublings. The coaming of the hatchways, which are also of heavy plating, also add to the strength of the structure in their vicinity. To replace the ordinary deck beams removed in the engine and boiler openings, there are special strong beams built up of heavy plates and angles. In the boiler space opening they are 14 inches deep and connected and stiffened by heavy angles. In the engine space there are introduced five extra-heavy girders, 45 inches deep, arranged both as to position and spacing to permit of the turbines being raised from their seats.

As the lower decks of the ship are complete only in the holds, the longitudinal strength in the engine and boiler spaces, which

occupy the greater part of the middle part of the ship, is maintained by girders and stringers.

The engine seating is of fore-and-aft box girders worked on the top of the inner bottom, which is constructed throughout with the same lines of longitudinal and inner floor worked at the same height forward and aft. Upon these girders supports for the turbines were bolted. As the reciprocating stresses are eliminated, and the propeller thrust is almost steam balanced, the structure is much lighter on the whole than it would have been for reciprocating machinery.

The stem of the hull is of forged steel with cast-steel forefoot, so as to take easily all the ends of the plating. The stern post and brackets are of cast steel. The center propeller shaft, as shown in Figs. 13 and 14, on Plate XXXVIII, passes through an aperture as in a single-screw ship, and the stern post, after the arching up to give satisfactory clearance over the tips of the blades, is carried down abaft the propeller, very nearly to the level of the center shaft, for the purpose of giving sufficient length of bearing for the rudder post. Higher up, the post is considerably swelled out, as shown in both views, in order to satisfactorily house the steering gear, which is placed beneath the water line to meet the requirements for service as an auxiliary cruiser.

In designing the shape of the stern post every care was taken to insure clean entrances, in order to reduce friction and eddy-making to the lowest possible extent. At a time it was contended that the post was unnecessarily heavy in structure; but while the designing was in progress the gigantic American steamer *Minnesota*, which is fitted with a similar kind of stern post, although she is fitted with reciprocating engines and of much lower speed, was brought to the works for repair with a crack at the arch of the post, and this circumstance induced the designer to make more allowance in scantling than otherwise would have been. Again, for the transportation of the post over a great distance—in fact, from Great Britain to Japan—it was necessary to design it in several pieces, and to allow

sufficient bearing surfaces for bolting the parts together. Thus it is heavier than if it were in one piece.

The rudder is also of cast steel, in two parts, connected together by horizontal flanges, and, as will be seen from Fig. 13, revolves on two pintles, which together with the gland at the head form the whole support against sideway pressure when maneuvering.

A singular feature of the stern post is the provision of a slot over the rudder, introduced so as to make the rudder apparently continuous with the stern post, and yet give sufficient clearance to lift the rudder when unshipping. The rudder is wholly below the water line, and its area is 218 square feet.

All the above steel castings were supplied by the Steel Company of Scotland.

The Launching of the Ship.—The *Tenyo Maru* being the largest ship yet built at the Mitsu-Bishi Works, much care and forethought were expended on the design and construction of the launching ways. Her weight on this occasion was 7,923 tons, including the launching cradle.

There were nine bilge blocks on each side. The keel was laid with a declivity of $\frac{1}{16}$ inch per foot, and the standing ways $\frac{6}{16}$ inch to $\frac{12}{16}$ inch per foot. The camber was 31 inches in the whole length of 602 feet. The standing ways extended from 29 feet abaft of the fore perpendicular to 79 feet abaft of the aft perpendicular. The sliding ways had a bearing length, from the fore end of the cradle to the heel aft, of 470 feet 8 inches, and as the width was 4 feet, the total area of bearing surface was 3,652 square feet, which gave a pressure per square foot of 2.17 tons when the total weight, including the cradle, was taken into consideration. There was, however, at the moment the stern floated a much greater pressure at the forward cradle, and this affected not only the fore cradle and the ways, but the floors and tank-girder construction. The examination, however, showed that everything had been of sufficient strength to withstand the great pressure, which was calculated to be 1,820 tons, decreasing to 450 tons as the bow left the ways. The greatest draught aft before lifting was about 28 feet,

while the maximum moment against tipping was calculated at 382,000 foot-tons.

The ways were placed at 23-foot centers. They were constructed of Oregon pine. The average length of the timbers forming them was about 45 feet, built up of four logs, and the butts were scarfed and bolted together by five 1-inch bolts. The average length of the sliding ways was also 45 feet. On account of the fine bow, a strong shelf plate of steel was fitted and supported by knee brackets, in order to form a butting surface, or a bearing, for the vertical members of the poppets.

On the standing ways there was laid first a coating of tallow and wax, secondly a coating of tallow and seed oil, and finally soft soap in blobs about 6 inches apart. On the sliding ways there was laid, before they were turned in on the top of the permanent ways, a thin coating of tallow and wax; next, tallow and seed oil; and, finally, soft soap in blobs. The total quantity of tallow thus used was about 3.6 tons, and of soft soap 0.5 ton.

Every possible care was taken in the process of releasing the ship, and many distinct and pre-arranged electric-bell signals with reply system were adopted in carrying out the instructions.

There were two dog shores, but in order to avoid any possible danger which might occur by hanging such a big ship on the dog shores alone, keel blocks under the forward part of the ship, about fifty in number, had sand bags put in between the wood blocks instead of being built up entirely of wood, and were left in place till the last moment. The sand bags were ripped open just after the dog shores had been knocked down by the falling weights, and the sand allowed to escape. Pressure on the blocks was thus rapidly released, and the total weight brought on the launching ways. There were hydraulic rams of 200 tons pressure abutting on the head of each of the sliding ways, to start the vessel if necessary; but they were not brought into use.

The time occupied in the first 20 feet of travel was 10.85 seconds, while for the 602 feet, the total length of the standing

ways, the time was 51 seconds. The maximum speed was 19.76 feet per second, equal to 11.7 knots, and the maximum acceleration was 98 feet per second per second.

The draught forward when the ship was afloat was 10 feet 4⅛ inches, and aft 16 feet 0¾ inch, with a mean of 13 feet 2 $\frac{7}{16}$ inches, the total weight being 7,593 tons, which excludes the 330 tons due to the launching cradles.

The Naming of the Ship.—The honors of the launch were performed by Mrs. Asano, the wife of the President of the Toyo Kisen Kaisha, who named the vessel the *Tenyo Maru.* It is interesting to note that "Ten" means "heaven" and "yo" the "ocean." The latter is also the second character of the owner's name Toyo, whilst the former is the first character in Chinese classic vocabulary called "Thousand letters," containing one thousand characters, and it is the wish of many that the Toyo Kisen Kaisha may continue to build ships for the remaining nine hundred and ninety-nine letters of the vocabulary.

The Passenger Accommodation.—The *Tenyo Maru* has six decks; the topmost, the boat deck, being about 33 feet above the load water line. Of this deck a plan is given on plate No. XXIX. Although it carries the large number of lifeboats with which the vessel is equipped, the greater part is available as a promenade for first-class passengers. At the fore end there is accommodation for officers, and at the aft end are the smoking room and lounge.

The next deck is known as the promenade deck, and it equals in length the boat deck. This deck is also arranged as a promenade, and an adequate idea of the area afforded is given by the plan, Fig. 3, on plate No. XXIX. At the forward end of the deck house are the drawing room, the reading room, and four suites of rooms, each consisting of a sitting room, bedroom, and a bath and toilet room. There are also four large family rooms. On the midship part there are four large staterooms specially well fitted, and at the after end there are nine ordinary state rooms. The public rooms on this deck and those on the boat and shelter decks are fitted with Messrs. J. Stone

& Co.'s vertical-motion ventilating square deck-house windows. The cabins and those of similar nature on the deck below are fitted with Messrs. J. Stone & Co.'s pivoted side scuttles with air inlet and outlet ventilating arrangement. The sitting rooms in the suites are each finished in different wood or style. A pair of folding berths and a sofa are placed to each room; the former is so designed that, when folded up, it assumes the appearance of a portion of the wall, having the berth bottom panelled like the wall, and the wall is recessed to receive the berth. Writing desk and dressing tables are also supplied. The rooms are upholstered in colored tapestry, which, with the different shades in carpets to match, gives a very fine appearance. The bedrooms are in correspondingly good taste, and Messrs. Hoskins & Son's "Neptune" bedsteads are fitted. The cabins on this deck are all finished in oak.

On the next deck, known as the shelter deck (Fig. 4 on plate No. XXIX), are located the dining saloon for first-class passengers, smoking room for intermediate passengers, and the hospital. There are also thirty-nine first-class state rooms. This deck marks the top of the molded structure of the ship, and therefore extends the full length of the vessel. But on no deck is the first-class passenger accommodation within 139 feet of the bow or 158 feet of the stern, while even the second-class passenger rooms are 125 feet from the stern. The importance of this point is associated with the reduction of disturbance of the saloon passengers, either from propeller action, which is, however, minimized on account of the adoption of turbines, or from the action of the sea, which is, perhaps, an insurmountable difficulty even with the greatest of ships. The special feature of the hospital is the introduction of Messrs. Hoskins & Son's patent equilibrium berths. Three of these are fitted in the hospital.

The upper deck (Fig. 5 on plate No. XXIX)—the first deck within the molded structure of the ship—has twenty-two cabins for first-class passengers, with auxiliary saloon, and a nursery for children. The intermediate-class accommodation is abaft the first-class quarters. There are sixteen cabins and a commo-

dious saloon. At the fore end there is accommodation for crew, and at the aft end for Chinese steerage passengers.

The main deck is entirely given over to the steerage passengers, forward for Japanese and aft for Chinese. On this deck 666 emigrants can be accommodated; Messrs. Hoskins & Son's patent galvanized-iron berths with sack bottoms are used.

There is one kitchen for the first and second-class passengers, with separate pantries adjacent to the respective dining saloon, also one for Japanese and one for Chinese. Many mechanical and electrical contrivances have been introduced by Messrs. Henry Wilson & Co., Limited, Liverpool, who supplied practically all the appliances, including patent roaster, steam stock pots, steam cooking boiler, grills, bain-maries, island ranges, steam ovens, bread and pantry ovens, rotary dough mixer, etc. The roaster has three revolving spits, two for joints and one for game, which are rotated by gear-driven electric motor. In the pantries there are carving table and hot press, bain-marie, milk, coffee and hot-water apparatus, electric dish-washing machine, egg boilers, etc.

The ventilation of the ship has had the most careful attention, and is associated with the heating appliances by means of the thermo-tank system, which will be referred to later, in connection with the electric equipment.

A special feature in the ship is the bath room and lavatory accommodation. Toilet apartments are arranged on all decks convenient to the state rooms. There are in all twenty-two bath rooms and twenty-five w.c.'s for first-class cabin passengers. The baths are all of white porcelain. The sanitary appliances were supplied from Messrs. Shanks & Co., Limited, Barrhead, Scotland, and Messrs. J. L. Mott's Iron Works, New York, U. S. A.

The ship is equipped with most improved laundry appliances, supplied by the Empire Laundry Machinery Company, Boston, U. S. A., including Cambridge washer, extractor and mangles, all electrically driven, steam-jacketed starch kettles, electric ironers, etc.

The Clayton apparatus is also fitted in the ship for fire extin-

guishing, disinfecting and ventilating the holds, bunkers and double bottoms.

The ship's boats are all fitted with Welin's quadrant davits, by which means any boat could be easily got out in spite of a considerable list which the ship may have at the time. Some of the boats are fitted with shifting chocks, permitting the boat to be chocked either fully inboard or along the extreme edge of the deck, so as to provide more promenading space on the boat deck.

Cargo and Navigating Appliances.—For dealing with the 6,000 odd tons of cargo carried fourteen derricks are fitted on the vessel, besides which there are two derricks, each capable of lifting 25 tons. In connection with these there are fourteen powerful steam winches.

The refrigerating installation is of Messrs. Hall & Co.'s combined and interchangeable type, including air cooler and water cooler, etc. The plant is capable of reducing the temperature of the insulated chambers from 70 degrees Fahr. to 20 degrees Fahr. in fourteen hours.

The installation of anchor gear in the vessel is by Messrs. Clarke, Chapman & Co., Limited. In the *Tenyo Maru* there are two cable holders for working the anchor cables, which are 2⅞ inches in diameter. Aft of the windlass are two capstans for warping, one on the port and the other on the starboard side. These are driven by the horizontal engine placed on the middle line of the ship. The engine has two cylinders, each 11 inches in diameter and 12 inches stroke, fitted with link-motion reversing gear and steam stop valve, and fitted with single and double-purchase gearing, and with clutch gear; so that either or both capstans can be worked at once. Two capstans are also fitted on the deck aft, similar to those in the fore part of the ship.

The steering gears are by Messrs. Brown Brothers, Limited, Edinburgh. There are two sets of steering gear, one located on the upper deck and the other on the lower deck well under the water line. The rudder itself weighs 27.5 tons, so that the gear is very heavy. The lower gear is designed to put the

rudder over in 20 seconds, the upper gear in 30 seconds. The connection of the upper gear is made by bolting a short fast tiller on the rudder head, to the bottom of the flat tiller carrying the steering engine, and the gear engaging in the quadrant.

The ship's telegraphs are all supplied by Messrs. Chadburn & Sons, Liverpool, including reply engine-room telegraphs, steering and docking telegraph, and Admiralty pattern tell-tales indicating "ahead" and "astern" of the machinery.

The Electric Installation.—In a ship of this class, carrying so many passengers, the electric installation is naturally an important feature in the equipment of the vessel, and an outline description of the appliances adopted will be of some interest. The generating plant, located on the main deck in the engine room, includes two generating sets, each giving an output of 75 kilowatts when running at 430 revolutions per minute. The large main switchboard has twenty circuits—eleven for the lighting of the ship, five for thermo tanks, one for ventilating fans, one for workshop machinery, one for galley machinery, and one for the searchlight projector. The lighting installation is arranged on the double-wire system. The mains of each circuit are led from the switchboard to a sub-main board, which again supplies three, four or six-way distributing boxes, each in its turn feeding four to eight-way small porcelain extension boxes, whence branch wires are connected up to the lamps. There are in all about 1,200 lights of the Tantalum type. The feeders for each motor are led from the switchboard to a double-pole fuse junction box with leads thence to each motor.

The thermo tank and ventilating fans form an interesting feature of themselves. The fifteen thermo tanks are fitted on the weather deck. They are designed for a threefold purpose. Each thermo tank can supply, through sheet-iron trunks, fresh air to the compartments, either cold or steam-heated to any desired temperature, or they can exhaust the foul air from the compartment. These operations are controlled by a series of lever-valves fitted in each thermo tank. The thermo tanks are capable of maintaining the temperature of the room at 65 degrees Fahr. when the outside atmosphere is 32 degrees Fahr.

The thermo tanks were supplied by Messrs. Stewart, of Glasgow.

The engine room is ventilated by four ventilators, each fitted with an 18-inch electric fan. As regards the ventilation of the saloons, state rooms and cabins, etc., there are 117 10-inch Portwayne bracket fans, ninety-eight for state rooms and nineteen for officers. There are also five 12-inch trunnion-bracket fans for the galleys and opium room. The dining saloon is ventilated by means of eight overhead fans, each 40 inches in diameter, the smoking room by one ventilator with 18-inch fan and five 10-inch trunnion-bracket fans, the lounge by four of 10-inch, the auxiliary-saloon by two of 12-inch, and the intermediate saloon by three 12-inch fans—all of the trunnion-bracket pattern.

As regards the telephone service, there are on the navigation bridge telephones communicating with the engine room, the lookout at the forecastle, the docking bridge aft, and the steering-engine room, all of pillar type. The telephones are of the loud-speaking marine pattern, and were supplied by Messrs. Alfred Graham & Co., London. In addition to the above there are intercommunication telephones fitted in the cabins of the captain, chief engineer and purser, also between three stations in the first-class accommodation (one each on the promenade, shelter and upper decks) and saloon pantry.

The navigation lights, telegraphs and principal compasses are also electrically lighted. There are 30 portable lamps for hold and bunker use, also eight cargo reflectors, each 4 to 50 candlepower lamps. The searchlight projector is of 16,000 candlepower. The navigation lights have a signal indicator placed in the chart room.

In connection with the watertight doors on the "long-arm" system, which are actuated by means of electricity, there are in the chart room controllers and an indicator board showing every door, and as the doors close the circuits in connection with each are cut in, and the lamps corresponding to each door are lighted up to show that the operation has been carried out.

Wireless telegraphy on the Telefunken system has been fitted, making the ship's equipment quite up to date.

Propelling Machinery.—Turning now to a description of the machinery, it may be said at the outset that the Mitsu-Bishi Company, when they obtained the right for manufacturing the Parsons steam turbine in Japan, realized that it was absolutely necessary to impart a thorough practical knowledge to their staff of the method of manufacture and the actual running under sea conditions of the turbines. They therefore despatched Messrs. Esaky, chief draughtsman in the engineering department, and Araki, the foreman fitter, both of them engineers of long and varied experience, to the Parsons works, where they spent a year, returning in time to instruct the foremen and men of the works, thoroughly to prepare for the fitting out the turbines of the *Tenyo Maru*. The turbines were constructed at the Parsons works and shipped out for the vessel.

There are three propellers, and as shown by the plans and sections of the machinery reproduced on Plate XXIX, the high-pressure turbine is on the center shaft, and one combined low-pressure ahead and an astern turbine on each of the two wing shafts. The turbines take steam at an initial pressure of 180 pounds. The low-pressure shafts are at 12-feet 6-inch centers on each side of the middle line of the ship. All the shafts are parallel with the middle line of the ship (Fig. 7), whereas they are at a slight angle to the line of the keel (Fig. 6). The intermediate shafts are of Messrs. Armstrong, Whitworth & Co.'s fluid-compressed ingot steel, whilst the propeller shafts are of Messrs. Richardson & Son's lock-fast iron, and about 20 per cent. heavier than the rule requirements.

The rotor drums are of forged weldless steel; the high-pressure drum is 76 inches in diameter, with over 130,000 blades, while the low-pressure drum is 106 inches in diameter, with over 300,000 blades, and the astern drum is 87 inches in diameter, with over 160,000 blades. Perhaps, however, a better idea can be formed of the magnitude of the work when it is stated that the total weight of the high-pressure turbine complete is over 67 tons, and of the low-pressure and astern turbine over 126 tons.

The illustration, Fig. 24, shows the method of assembling

the blades and forming them into segments, according to the latest practice at the Parsons works. It will be seen that for temporary use castings are made and bolted together to represent part of the circumference of the casing, or of the rotor, the former concave, the latter convex; and these form a groove exactly similar to that into which the segment is subsequently to be caulked in the casing and rotor respectively. The wire on which the blades and distance wedge pieces at the base are threaded, by holes suitably formed, is secured at one end of the casting, and by means of a caulking tool and hammer the lads string the blades and wedges alternately into place, ready for another workman to put into position the strip, and bind the blades together, as shown in Fig. 24. These strips fit into indents cut on the edge of the blade, and are laced by a wire and fixed with silver solder. In this way it is found possible to assemble the blades into segments while the casings and rotors are being machined, and the final operation of caulking the segments into grooves is quickly accomplished. The lacing of the blade gives greater security than the former practice of wedging each blade separately into the groove in the casing or rotor. From Fig. 23 it will be seen that the longer blades have two binding strips, while the shorter blades have only one. In some instances, although not in the *Tenyo Maru*, there are three such strips.

The over-all length of the turbine rotors, including the bearing, is in the case of the high-pressure turbine over 24 feet, and of the low-pressure and astern turbine over 33 feet. The turbine casings are of cast iron. The bottom portions of the steam and exhaust ends are cast in one, with bearing stools. The governing gear, fitted to each of the turbines, is so arranged that any increase beyond the required revolutions in any of the turbines shuts off the steam supply from the turbines until the revolutions fall to the normal speed. An emergency governor is provided to entirely stop the turbines should any serious increase in the revolutions take place.

The gland for the shaft passing through the end of the turbine is rendered steamtight by Parsons' latest improved method.

Boilers.—There are thirteen single-ended boilers, arranged in two separate boiler rooms, as shown in Figs. 7 and 8 on Plate No. XXIX. They are designed to work under Howden's system of forced draft, and are also arranged to burn oil fuel. There are four large fans, two in each boiler room, each driven by an independent engine. They were supplied by Messrs. J. Howden & Co. The oil-burning arrangements are of Lassoes' low-pressure system, and there are four special blowers of Green's vertical pattern, each driven by an independent steam engine for atomizing oil fuels. These four blowers take hot air from the hot-air duct of Howden's system through a common trunk, and discharge into a common pipe, by which means the hot air under a pressure is distributed to the oil burners. The furnaces are of the Morison type. The funnels are two in number, elliptical in shape, and rise 120 feet high above the furnace bars.

The Condensers and Pumps.—There are two main condensers, two independent twin air pumps and two Parsons' augmentor condensers. Each main condenser deals with each low-pressure turbine. The air pumps are of Weir's high-vacuum system and merchant-service design, having cast-iron tops and bases with gun-metal barrels, gun-metal buckets, bronze rods and special valves. The two sets of centrifugal circulating pumps are of the Mitsu-Bishi make, each having suction and discharge branches, and driven by open engines. There are two surface feed heaters. The shells of the heaters are of mild steel, and tubes and tube plates of brass. The main feed pumps are supplied by Messrs. Weir, and consist of two pairs of double-acting pumps. Each pair is capable of supplying the boilers when the turbines are working at their full power. The pumps work at ten strokes per minute, and are so connected that either pump may serve any boiler. These pumps have complete gun-metal water ends, gun-metal buckets, manganese-bronze rods, steel piston rods, and bronze valves in gun-metal seats. Two Weir direct-acting oil-circulating pumps have also been furnished, their duty being to circulate oil through the

turbine bearing, a constant and important duty, necessitating pumps of great reliability: one is for ordinary working, the other is a stand-by. There is also one Weir pump for water circulation of oil-cooling tank. Two Weir patent evaporators, of merchant-service pattern, are fitted, and are each capable of producing 50 tons of fresh water per day. A separate surface condensing plant, consisting of a condenser of Morison's "Contraflo" type circulating pump, Morrison's patent grease extractor is also provided for the auxiliary machinery for use in the port.

The Trials.—The trials of the *Tenyo Maru,* which occupied nearly three weeks, involved seven series of trips; the first three—the preliminary and progressive trials—were run on February 10, 13 and 15, 1908; the official trial on February 19, 1908, and the last three—the coal-consumption trials—on February 22, 25 and 27, 1908. The performance of the ship was exceptionally favorable from beginning to end. The steaming tests naturally excited considerable attention among marine constructors, and were each attended by representatives of several important interests.

The official trial consisted of six runs at full speed over the measured 3.458-knot Government course. The full speed guaranteed by the contract was 19 knots, but on this trial 20.62 knots was obtained. The results of the six runs are given on the following table:

Speed, in Knots, on Measured-Course Trials.

1st run, - -	20.50					
		20.49				
2d run, - -	20.48		20.56			
		20.63		20.59		
3d run, - -	20.78		20.61		20.61	
		20.59		20.62		20.62
4th run, - -	20.39		20.62		20.62	
		20.65		20.61		
5th run, - -	20.91		20.60			
		20.55				
6th run, - -	20.18					

On several occasions ahead and astern trials were made, and it was found that the time occupied to bring the vessel to a dead stop by putting the machinery from full ahead to full astern was 3 minutes 30 seconds, and to full ahead from full astern 3 minutes 30½ seconds. The satisfactory results of the *Tenyo Maru's* trials were not only of great importance from the point of view of turbine engineering, but must have been most pleasing to the Mitsu-Bishi Dockyard and Engine Works, who also attained equal success with the *Chiyo Maru* for the same service.

In conclusion, it may be added that the Mitsu-Bishi Dockyard and Engine Works have been lately provided with an experimental tank, fitted with apparatus and machinery of a most improved design, supplied by the well-known firm of Messrs. Kelso & Son, of Glasgow; and doubtless some modifications or improvement will be made on the third ship from the experimental data obtained in the tank. We hope to publish a description of this marine laboratory on some future occasion.—"Engineering."

S. S. President de Leeuw.—We recently announced that the Soc. An. de Remorquage à Hélice, of Antwerp, had decided to build another powerful sea-going tug and salvage boat combined, and had entrusted the order to the Kattendyk Works (Soc. Anon.) of that port.

In her official trial run on the Scheldt the result was most satisfactory, the engines working without a hitch, developing over 1,000 horsepower on a moderate consumption, and the ship in ordinary working condition making over 13 knots.

Mr. G. F. Amor, M. I. N. A. (directeur of the Kattendyk Works, Soc. An.), has favored us with the few following details of the vessel and her machinery: Length between perpendiculars, 124 feet; breadth, 24 feet; depth, 14 feet.

Flush deck, with bridge deck, on which is placed the steering house, and chart room beneath, with powerful steam steering gear. Under this deck are built side houses for salvage gear, stores, lavatories and large galley. The towing apparatus is exceptionally strong and convenient to manipu-

late. Steam windlass and stockless anchors and steam capstan, breakwater forward; crew are berthed aft, and forward there is a small but handsome saloon for passengers or others who may require to remain on board on salvage operations. There are two masts with fore-and-aft canvas, and one double funnel. The accommodation is steam heated. The ship is built entirely of Siemen's-Martin steel to Germanischer Lloyd highest class, the scantlings being 10 per cent. over their requirements. There are five watertight bulkheads and five water-ballast tanks, side and cross bunkers with a capacity of thirty days' steaming, and, in view of the important business which the owners have in towing in the Baltic, special provision has been made against the ice by additional framing and specially-designed stem, etc.

The ship has fine lines and a high degree of stability, having deep bilge keels as well as bar-keel rudder of single-plate type with flange coupling.

The engine is triple-expansion, surface-condensing, cylinders of $16\frac{3}{8}$, $26\frac{3}{4}$ and $44\frac{7}{8}$ inches, and stroke $29\frac{1}{2}$ inches, steam being supplied by two single-ended boilers 11 feet 2 inches by 9 feet 10 inches, of 185 pounds pressure. The H.P. cylinder is fitted with a piston valve and the I.M. and L.P. with balanced slide valves. The tunnel shafting is arranged in lengths suitable for removal and the propeller (designed and cast by Zeise, of Hamburg) can be removed and replaced without drawing the tail-end shaft. The Cedervall tube and Aspinall's governor have been fitted, and in the engine room are also fitted Caird & Rayner's evaporator, feed heater and filter. Special attention has been paid to the pumping plant, naturally, in view of the salvage services the vessel is designed to render. A 10-inch Gwynne centrifugal pump and 8-inch and 6-inch duplex pumps, by A. G. Mumford, have been fitted, together with a very complete installation of valve boxes for the suction and delivery hoses.

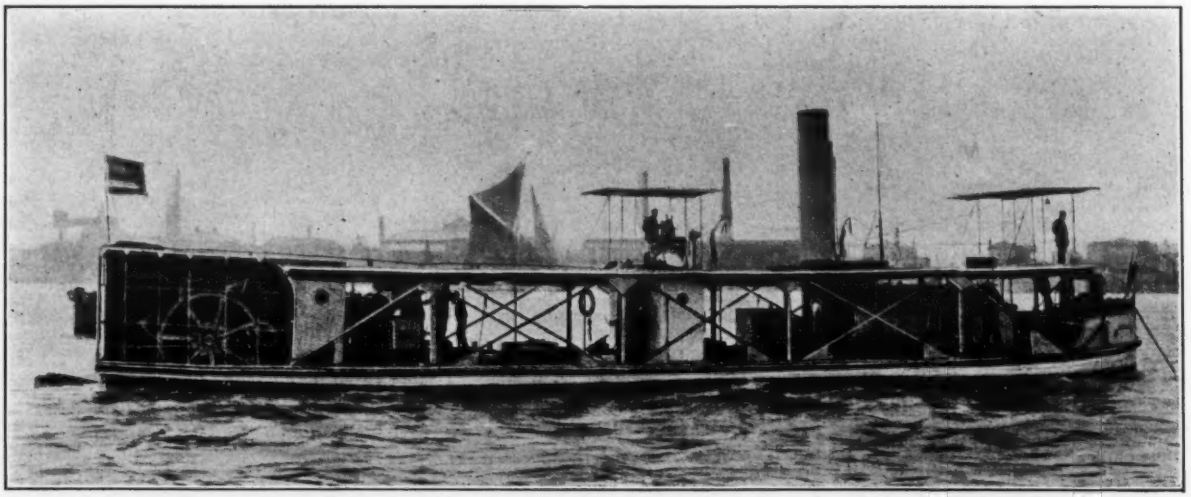
Such a powerful and complete vessel should prove of the greatest utility to the mercantile marine in Antwerp particularly, and the north of Europe generally, and we congratu-

late builders and owners alike in producing and owning such an exceptionally installed and serviceable boat. The fittings and accommodation of this tug are exceptionally fine, and the owners and those who have seen the vessel have expressed their pleasure at the handsome appearance of the saloon and interior.

It is interesting to note that one of the first commissions of the *President de Leeuw* was to tow the Royal yacht *Osborne* from Portsmouth to London. She previously performed a very quick tow down Channel, returning to Flushing at about 13 knots per hour.—"The Steamship."

We illustrate a Shallow-Draught Steamer recently built by Messrs. G. Rennie & Co., at their Greenwich yard, to the order of the Crown Agents for the Colonies, solely for towing purposes in shallow rivers of Northern Nigeria. The view shows the steamer as she appeared on the Thames; the following are her general dimensions: Length, 100 feet; breadth, 19 feet 6 inches; depth, 5 feet 6 inches; draught, loaded, with 10 tons of coal and stores, 3 feet 3 inches.

The hull is divided by transverse and longitudinal bulkheads, and is strongly stiffened with a system of tie rods, hogging girders and king posts of exceptional strength. Owing to the care which has been taken in stiffening the vessel a total absence of vibration was experienced during the trials, even at full speed. Accommodation for the crew is provided forward, the steering wheel is placed amidships, the pilot house being forward. By this means the steersman has complete control over the vessel. In steaming amongst the river traffic no difficulty was experienced in maneuvering. The vessel is propelled by stern wheels of the divided type, with feathering floats, the engines, of the compound non-condensing pattern, being situated in the center of the vessel. The boiler is of the locomotive marine type, the exhaust steam entering the funnel. As above stated, the vessel has been constructed solely for the purpose of towing, and great interest was experienced on the trial as to the way she would be able to handle and tow the ordinary Thames barge alongside; the results compared very favorably



SHALLOW-DRAUGHT STEAMER FOR NORTHERN NIGERIA.

with screw tugs drawing far more water. The speed of the vessel when running light was 9½ knots, which, considering her length and the fact that a high speed when running alone was not aimed at in the design, is most satisfactory. The guaranteed horsepower of the vessel—namely, 400—was exceeded by 7 per cent. Messrs. Plenty, of Newbury, were the sub-contractors for the machinery. Both the hull and machinery have been built under the superintendence of Messrs. Ridsdale, Wells & Kemp.

Laurentic.—Special interest attaches to the triple-screw Dominion liner *Laurentic,* from Messrs. Harland & Wolff's yard at Belfast, on account of the adoption in this vessel of a combination of reciprocating engines with a low-pressure turbine, the *Laurentic* being the first passenger steamer designed with this arrangement of machinery. Moreover, it has been generally assumed that the adoption of this novelty in the *Laurentic* is some indication of the owners' intentions with regard to the machinery of the other large liners which they are contemplating. This arrangement of machinery constitutes the vessel a triple-screw steamer, each of the wing propellers being driven by four-crank triple-balanced engines, and the central propeller by a turbine.

The object is, of course, to retain the advantages of the highly-perfected balanced reciprocating engines and at the same time get the benefit of the further expansion of steam in a low-pressure turbine, while avoiding the necessity for an astern turbine, which is essential in steamers fitted with turbines only. In this vessel, both for going astern and maneuvering in and out of port, the reciprocating engines will be more than sufficient, as they will develop over three-fourths of the total combined horsepower.

The *Laurentic* will be the largest vessel in the Canadian trade, being 565 feet long by 67 feet 4 inches beam, and 14,500 tons gross. She is designed to carry a large quantity of cargo, also a full complement of passengers—about 230 first-class, 430 second-class and over 1,000 third-class. As, of course, is well known, the double bottom, in addition to being an element of

strength and security, provides space for water ballast, which is also carried in the fore and after peaks. There are six cargo holds, and the bunkers are specially arranged to facilitate the coaling. The whole of the passenger accommodation has been arranged on generous lines. The *Laurentic* will signalize the entry of the White Star Line into the Canadian trade.—"Engineer."

Post Office Boat for Uruguay.—An interesting little vessel, 90 feet long by 14 feet beam, named the *Correo del Uruguay*, has just completed her trials on the Clyde, and will shortly be shipped to Montevideo. She has been built to the order of the Uruguayan Government by Messrs. Yarrow & Co., Ltd., Glasgow (formerly of Poplar, London), and is intended for loading and unloading mails from the steamers that call at the port of Montevideo. She is built of galvanized steel, and provided with one set of triple-expansion surface-condensing engines and a Yarrow water-tube boiler. There is a deck house aft containing the saloon and sleeping accommodation for three officials, and also a sorting room for mails. In the forward cabin there is accommodation for four assistants, and below deck there is sleeping space for the crew. There are two holds for carrying the mails, the forward hold being intended for heavy packages, in connection with which a derrick is fitted on the mast; the after hold is intended for the lighter mails. A complete electrical installation is provided for lighting the internal parts of the vessel, and a small searchlight is fitted on the top of the forward cabin. A stout hard-wood rubbing piece is worked all round the hull to serve as a fender in going alongside the mail steamers out in the roads. This little vessel is also provided with a 37-mm. Armstrong quick-firing gun forward. The official trial was made at the mouth of the Clyde in the presence of the Uruguayan authorities and the representatives of Lloyds, when a mean speed was obtained of 11.4 knots at 120 pounds steam pressure, and 13.3 knots at 220 pounds. The *Correo del Uruguay* will be shipped whole to Montevideo on the deck of a cargo steamer.

ASSOCIATION NOTES.

At a regular meeting of the Society, held on October 6, 1908, the following officers were nominated for election as President and Members of the Council for the year 1909:

For President:

Rear Admiral JOHN K. BARTON, U. S. N.
Captain F. H. ELDRIDGE, U. S. N.

For Secretary-Treasurer:

Lieutenant H. C. DINGER, U. S. N.
Lieutenant J. B. GILMER, U. S. N.

For Members of Council:

Commander H. P. NORTON, U. S. N.
Commander F. C. BOWERS, U. S. N.
Commander GUSTAV KAEMMERLING, U. S. N.
Engineer-in-Chief CHAS. A. MCALLISTER, U. S. R. C. S.
Commander W. W. WHITE, U. S. N., Retired.
Commander W. STROTHER SMITH, U. S. N.
Commander C. W. DYSON, U. S. N.

At a special meeting of the Society, held on October 29, 1908, the resignation of Commander Theodore C. Fenton, U. S. Navy, as Secretary-Treasurer was accepted, and Lieutenant H. C. Dinger, U. S. Navy, was appointed as Secretary-Treasurer for the completion of the year 1908.

MEETING OF THE A. S. M. E.

The next monthly meeting of The American Society of Mechanical Engineers will be held in the Engineering Societies' Building on Tuesday evening, January 12. The paper will be by Carl G. Barth, of Philadelphia, upon The Trans-

mission of Power by Leather Belting, illustrated by lantern slides. It will be a comprehensive summing up of the theory and practice of belting in which conclusions are drawn from the work of Lewis, Bancroft, Bird and others, who have made experiments upon the transmission of power by belting. Valuable charts have been prepared by the author for the solution of belting problems.

Mr. Barth's long experience in the scientific running of machine tools in connection with the introduction of improved shop methods, has shown the need of definite data for the application of belting to machinery and led to the development of the results contained in his paper. His data have been applied to belting in different plants for many years, giving an unusual opportunity to study the problem in great detail.